COMMUNITY ADAPTATION PROJECT

DAWSON CLIMATE CHANGE ADAPTATION PLAN

November 2011

Canada
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Northern Climate ExChange
YUKON RESEARCH CENTRE • Yukon College

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TAKING ACTION ON CLIMATE CHANGE

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DAWSON CLIMATE CHANGE ADAPTATION PLAN

Prepared by the Dawson Adaptation Project Team:

Ryan Hennessey

Community Adaptation Project Manager

Sebastian Jones

Dawson Local Adaptation Coordinator

Stephen Swales

Dawson CAVIAR, Ryerson University

Frank Duerden

Dawson CAVIAR, Ryerson University

With support from:

Erica Beasley	*Dawson CAVIAR, Ryerson University*
John Lenart	*Yukon Agricultural Association*
Renée Mayes	*Tr'ondëk Hwëch'in First Nation*
Jim Taggart	*Conservation Klondike Society*
Mark Wickham	*Klondike Visitors Association*
Gerry Couture	*Natural Resources Specialist (retired)*
Jim Regimbal	*City of Dawson*
Norm Carlson	*City of Dawson*
Antoni Lewkowicz	*University of Ottawa*
Aynslie Ogden	*Forest Management Branch, Government of Yukon*
Rick Janowicz	*Hydrology Section, Government of Yukon*
Robin Walsh	*Transportation Engineering, Government of Yukon*
Val Walker	*Social Economy Research Network of Northern Canada*
Lacia Kinnear	*Northern Climate ExChange*
Arelia Werner	*Pacific Climate Impacts Consortium, University of Victoria*
Ian Church	*Senior Science Advisor, Government of Yukon (retired)*
John Streicker	*Northern Climate ExChange*
Trix Tanner	*Department of Fisheries and Oceans*
Robert Clark	*Tourism Product Development and Research, Government of Yukon*
Greg Finnegan	*Yukon Bureau of Statistics, Government of Yukon*

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We are especially grateful to all of the participants in this project for their enthusiasm and interest.

FOREWORD

The Local Advisory Committee for the Dawson Climate Change Adaptation Plan is a group of volunteers who feel strongly that climate change will bring great changes to Dawson and the area around it. It also feels the community needs to plan how to adapt to, and live with, the coming changes, and that there are opportunities to be seized as well as hurdles to overcome.

The Advisory Committee is confident Dawson will become a stronger more viable community if this Adaptation Plan is used in the way it is intended.

So, how should this plan be used? Too often, visionary documents are produced that languish on shelves until their very existence is forgotten. Ideally, this plan would be consulted whenever legislation is drawn up in Dawson so that the intended actions will help move Dawson further along the path towards being a truly resilient community.

If this sounds rather like the Integrated Community Sustainability Plan (ICSP), this is no coincidence. However, the ICSP does not directly address climate change; this plan does. Through this project, scientific expertise in many fields has been integrated with the wisdom of our community members and Elders to create a document that can complement the ICSP and make it stronger.

So we invite you to visit this report and keep it in mind as our community evolves; maybe ask yourself when considering new projects: How does this action help Dawson adapt to climate change?

Sebastian Jones

Chair, Dawson Local Advisory Committee

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EXECUTIVE SUMMARY

ABOUT THE DAWSON ADAPTATION PLAN

The Dawson Adaptation Plan is based on a collaborative process that draws on the experience and knowledge of residents and integrates it with scientific expertise. The plan is primarily intended as a resource for community use and to support other planning and decision-making processes in the study area, which is defined by the Tr'ondëk Hwëch'in Traditional Territory. The Dawson Adaptation project team itself is made up of members of the International Polar Year Dawson Community Adaptation and Vulnerability in Arctic Regions (CAVIAR) team, and the Northern Climate ExChange (NCE).

The Tr'ondëk Hwëch'in Traditional Territory was selected as the study area boundary because it allowed a broad area from which to assess potential environmental changes that may affect the community. However, this study focused on how climate change may affect the community. The community in turn focused on those aspects of their environment that affects them the most, the infrastructure and the townsite of Dawson.

Collaboration between the project team and Dawson residents was an important component of this project. From the beginning, we have worked closely with local residents. Guidance in the development of this plan was provided by the Dawson Local Advisory Committee, which included representatives from the Conservation Klondike Society, government of the Tr'ondëk Hwëch'in and the City of Dawson. Membership of the Local Advisory Committee was determined based on those community stakeholders perceived to be at risk at the beginning of the planning process. The role of the Local Advisory Committee is to ensure community priorities were reflected in the planning process and to provide guidance on the planning process itself. Yukon government voluntarily chose not to participate because of the community nature of the planning process.

The Dawson Adaptation Plan was developed in two parts. During the first part of the planning process, the project team worked with residents to determine how they may be affected by climate change. Community knowledge of how climate change may affect residents was incorporated into the planning process through a number of open houses, individual interviews completed through the Dawson CAVIAR project, and through community input sessions that brought local experts together to discuss the implications of climate change in the community. The resulting community vulnerability scenario was then enhanced by a second workshop in the community and with a Technical Advisory Committee. The Technical Advisory Committee was composed of government and academic experts from outside the community and sought to reinforce local findings through the integration of scientific/expert knowledge.

In the second component of the planning process, the project team worked with the Local Advisory Committee to distill the community vulnerability scenario into a list of consequences that climate change may have for residents. Each consequence was evaluated based on a risk assessment framework. The risk assessment evaluates the consequences of climate change based on three predetermined characteristics of resilience. Resilience, in this context, is defined as the ability of the community to maintain its functions in the face of internal and external change. For the purposes of this plan, resilience was characterized by: the ability of the community to respond to each consequence, the severity of the consequence, and the likelihood of the event. Priorities were determined based on the relative ranking of each consequence.

Plan development was guided by a vision statement prepared by the Dawson Local Advisory Committee:

> *Dawson City and its hinterlands will be a self-sustaining society, a community that lives within the limits of the local ecosystem and serves as a haven for its residents in an uncertain world.*

It will achieve this by:

- taking steps to increase its resilience;
- actively promoting self-sufficiency;
- increasing our knowledge of the environment around us; and
- developing ways to adapt to sudden changes in society and the climate.

The vision statement established community priorities for the project team and set the tone for the plan recommendations.

CLIMATE CHANGE AND DAWSON

Climate change is expected to greatly alter the regional characteristics of Dawson, as well as increase the risk to residents with respect to damaging environmental impacts. Historical trends for temperature, precipitation, and streamflow for Dawson and the surrounding area were assessed by the Pacific Climate Impacts Consortium (PCIC) in order to give some indication of how climate conditions are being affected locally (Werner *et al.*, 2009). PCIC's findings suggest that climate change has already taken place in the Dawson region. Projected changes to the climate of Dawson City were derived from the Canadian Regional Climate Model (CRCM) for the 2050s (*i.e.*, years 2041-2070).

Temperature and Precipitation

To illustrate how climate change may affect Dawson, baseline annual temperature and precipitation data for Dawson from 1961-1990 was established. Mean annual temperature in Dawson for this period was -5.3°C. An annual range of precipitation from 200 mm to 500 mm occurred in the Dawson region between 1961 and 1990. Northeast of the community of Dawson, mean annual precipitation was higher and ranged from 400 mm to 800 mm during the same interval (Werner *et al.*, 2009).

A relatively uniform increase in annual temperature of 2.5°C to 3.5°C is projected for the 30-year period of the 2050s. Annual precipitation in the Dawson region is projected to increase by 10% to 40%. More precipitation is expected during winter months than during summer months. A 30% to 50% increase in winter precipitation is projected, while summer months may experience an increase of only 10% to 30% (Werner *et al.*, 2009).

CLIMATE CHANGE CONSEQUENCES AND RECOMMENDED ADAPTATIONS FOR DAWSON

The consequences of the climate change vulnerabilities were identified in collaboration with the community. Eleven regional/non-community-based vulnerabilities emerged from the Dawson community impacts scenario. These were reported because they occur within the study area boundary and because residents identified them as being of concern. These vulnerabilities differ from community-based consequences of climate change because the community cannot effectively respond to them.

Fifty-two consequences of climate change were identified in the Dawson community scenario. Each consequence stems from climate-induced changes in regional flooding, forest fires, and weather. These changes may affect access, health, land-use and the local economy. Fourteen opportunities were also identified in the Dawson community climate change scenario. These opportunities stem from climate-induced changes to the regional forest fire regime, seasonal weather changes, tourism and recreation, permafrost degradation (as it applies to placer mining), and a local economy that will likely favour residents.

Priority risks were characterized by a high level of both impact and likelihood of the identified consequence, and by a low observed ability of the community to respond. A high priority was also assigned if one or more of the risk assessment criteria were unknown. This is because a need exists to increase the level of knowledge associated with the consequence. Priority opportunities were identified based on the existing adaptive capacity of residents to respond to favourable conditions and the likelihood that the opportunity would emerge.

It is anticipated that, over time, improved climate change projections and additional scientific research will allow for greater certainty in decision making. For the immediate future, it is suggested that the recommendations of this plan be implemented in keeping with upcoming global timetables. Specifically, the global community is anticipating that emission controls are necessary and that specific carbon cuts will be required by 2020. At that time, based on the success of nations to curb their carbon emissions, communities will have greater certainty of the severity of the climate changes that they must face. The project team therefore suggests that the following actions be taken in the Dawson region by 2020. These actions should be led by the community and supported by various institutions. We also recommend that this plan be updated by the year 2020 to reflect the success or failure of the global community to curb their carbon emissions.

Adaptations Recommended for Immediate Implementation

- Maintain or develop research and monitoring to observe climate change and evaluate possible climate change impacts and responses.
- Integrate climate change assessment into rural planning processes.
- Update the Emergency Measures Ordinance (EMO) to reflect possible climate change vulnerabilities.
- Investigate the need to raise the existing level of the dyke. Determine who is responsible for the work.
- Investigate flood proofing of sewage facility.
- Complete a detailed permafrost assessment that would build upon and update the assessment completed by EBA Engineering Consultants Ltd. in the 1970s.
- Continue highway vulnerability assessment and action planning (*e.g.*, build on experiences in, and around, Beaver Creek, YT).
- Complete the hydrogeological testing of the Quigley Solid Waste Facility.
- Designate fiscal responsibility for remediation of abandoned waste disposal sites.
- Explore the feasibility of technologies that will conserve permafrost.
- Continue weed-pull programs.
- Communicate to present and future generations the need to respect fish and wildlife.

- Diversify economy by supporting emerging markets.
- Use local materials when implementing projects.
- Update/implement the Official Community Plan (OCP) recommendations relating to Recreation and Parks and Open Space (see Section A.5.5 of the Official Community Plan).
- Advertise local produce.
- Explore food storage.

Adaptations Recommended for Implementation by 2020

- Implement preparedness education to respond to potential climate change-related emergencies.
- Ensure necessary resources are available to repair any damages within the plan boundary.
- Develop education programs to assist residents in making sound decisions when coping with, or preparing for, climate-induced changes in the community.
- Re-establish experimental farms (*e.g.*, Swede Creek) and investigate local agricultural options/alternatives.
- Research and/or release information about possible flooding events.
- Investigate the potential of drought and its impacts on the Dawson region.
- Create emergency storm shelter systems within the community.
- Construct helicopter pads for emergencies as needed.
- Change road materials - use stronger materials.
- Provide more monitoring in the area in order to document changes in water quality.
- Complete a risk assessment that also inventories abandoned dump sites in the Dawson area.
- Incorporate flexible regulations and policies into rural land-use planning.
- Explore feasibility of fish hatchery.
- Ensure that climate change is incorporated into forestry management plans.
- Study how small animals (*e.g.*, those species toward the bottom of the food chain) react to climate change.
- Ensure building codes are congruent with the expectations of a changing climate.
- Re-brand community marketing strategy to offset long distance aspect of travel (*e.g.*, create slogans such as “You’ve come so far to get here; stay a little longer.”).
- Emphasize grassroots culture/unique events (*e.g.*, music festival).
- Expand existing trail networks.
- Coordinate the expansion of the downhill ski hill with EMO implementation.
- Incorporate local infrastructure and natural features into climate change adaptation (*e.g.*, convert firebreaks to trails).

NEXT STEPS AND CONCLUSIONS

Some selected adaptations will be implemented as a component of the Dawson Adaptation Project with funding from the Northern Strategy Trust. These projects will be selected by the Dawson Local Advisory Committee. To ensure the selection of relevant and successful implementation projects, the Local Advisory Committee prepared the following terms of reference:

- Have broad appeal.
- Have high visibility.
- Have high relevance/utility.
- Produce readily measurable results.
- Reduce the carbon footprint of the community, or have a minimal footprint.
- Leverage other funding.
- Attract partners.
- Be built upon later.
- Provide local employment.
- Tie into and/or build upon existing plans.
- Increase local resilience.
- Use local resources and materials.
- Be characterized by financial sustainability that continues past the implementation deadline (July 2010).

Projects will be implemented from August 2009 to June 2010 by the Dawson Adaptation Coordinator. A full implementation report will be provided at the conclusion of the implementation period in summer 2010.

Mainstreaming Climate Change in the Community

Mainstreaming climate change is the integration of climate change into standard planning procedures. Many of the adaptations identified in this plan can be integrated into other plan developments or updates. Specifically, the planning team has identified how climate change may influence a future update of the Dawson official community plan, as well as influence sectors such as emergency response, fire management, infrastructure and land-use planning in the region.

Addressing Uncertainty and Climate Change in the Dawson Region

While this report has made every attempt to assess uncertainty associated with the identified climate change consequences, every effort should still be made to increase our knowledge of how climate change may affect us. The project team suggests that integrating climate change mitigation and adaptation efforts will likely result in a more confident action strategy by providing a solid rational for decisions, in addition to providing the balanced and effective response to climate change suggested by the IPCC. We have also found that increased monitoring and research is desperately needed in Dawson and the whole of Yukon.

KEY TERMS

Active layer is the uppermost part of soil that undergoes annual freeze and thaw in areas underlain by permafrost (Davis, 2001).

Adaptation is an adjustment in natural or human systems in response to actual or expected climate change impacts or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007b).

Adaptive capacity is the ability of a system to adjust to climate change, either to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC, 2007b).

Adaptation strategies are ways in which communities change over long periods of time by modifying activities, institutions and rules to ensure that their interests are achieved (Berkes and Jolly, 2001).

Climate is the average weather that occurs over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization (IPCC, 2007a).

Coping mechanisms are short-term responses at the household/individual level at smaller spatial scales (Berkes and Jolly, 2001).

Maladaptations are adaptations that increase the vulnerability of communities (IPCC, 2007b).

Mitigation is an action intended to reduce the onset and severity of climate change and includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks (IPCC, 2007b).

Place identity is the manner in which a place informs the identity of a person or people and generates the perception of insiders and outsiders (Shamsuddin and Ujang, 2008).

Precautionary principle recognizes that in the absence of scientific certainty, conservation measures can and should be taken when there is knowledge of a risk of serious or irreversible harm to the environment and/or resources using best available information (DFO, 2008).

Resilience is "…the capability of a system to maintain its functions and structure in the face of internal and external change and to degrade gracefully when it must." (Allenby and Fink, 2005, p. 1034).

Susceptibility is the degree of exposure to dangerous hazards (Keim, 2008).

Sustainable development requires meeting the basic needs of all and extending to all the opportunity to satisfy their aspirations for a better life (Bruntland, 1987).

Vulnerability to climate change is the degree to which systems are susceptible to, and unable to cope with, adverse impacts (IPCC, 2007b).

LIST OF ACRONYMS

AGO	Australian Greenhouse Office
AHCCD	Adjusted Historical Canadian Climate Database
AO	Arctic Oscillation
BST	Bituminous Surface Treatments
CAVIAR	Community Adaptation and Vulnerability in Arctic Regions
CBMP	Circumpolar Biodiversity Monitoring Programs
CRCM	Canadian Regional Climate Model
EMS	Emergency Medical Services
EMO	Emergency Measures Ordinance
ENSO	El Niño/Southern Oscillation
GCM	Global Climate Model
GEOSS	Global Earth Observation System of Systems
ICSP	Integrated Community Sustainability Plan
IPY	International Polar Year
NCE	Northern Climate ExChange
OCP	Official Community Plan
OMAFRA	Ontario Ministry of Agriculture Food and Rural Affairs
PCIC	Pacific Climate Impacts Consortium
PDO	Pacific Decadal Oscillation
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RCMP	Royal Canadian Mounted Police
SAD	Seasonal Affective Disorder
SAON	Sustained Arctic Observing Networks
UNBC	University of Northern British Columbia
YESAB	Yukon Environmental and Socioeconomic Assessment Board
YG	Yukon government
YLUPC	Yukon Land-Use Planning Council

INTRODUCTION

As the climate changes, so too will life for Yukon communities. For Dawson City, Yukon, the consequences of changing environmental conditions may include permafrost thaw, increased forest fire risk and flooding. Just as the historic record of the community demonstrates that these natural hazards can have a significant impact on the socio-economic health of the community, it also provides evidence that Dawson residents have extensive experience in responding to environmental risk.

The Dawson Adaptation Plan draws on this experience and integrates it with scientific expertise. The plan is primarily intended as a resource for community use and to support other planning and decision-making processes in the study area, that is, the Tr'ondëk Hwëch'in Traditional Territory (Figure 1). It first examines how climate change may create vulnerabilities for the residents of Dawson City by assessing how shifting climate conditions will affect the socio-economic, cultural and environmental conditions in the community. The resulting plan primarily stems from local/traditional knowledge and is focused on assessing and managing the potential risks associated with climate change.

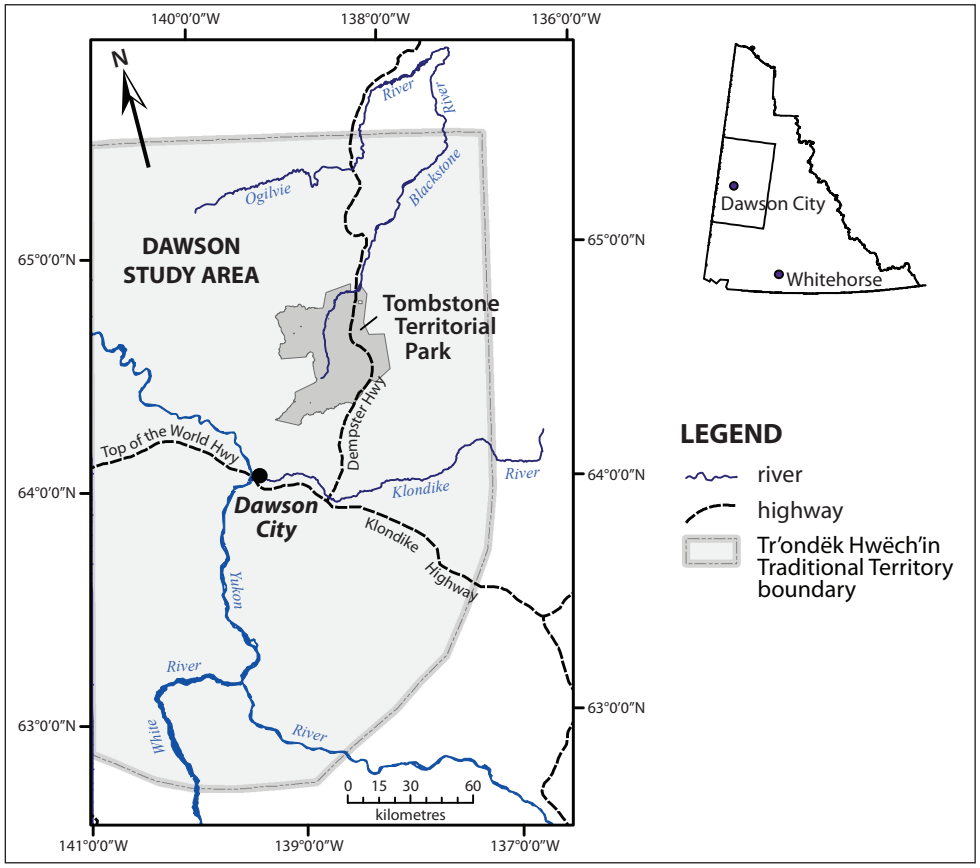

Figure 1. *Map of Dawson Adaptation Plan study area.*

The Tr'ondëk Hwëch'in Traditional Territory was selected as the study area boundary because it is large enough to allow for an assessment of any potential environmental changes that may affect the community. However, this study focused on how climate change may affect the

community of Dawson City. The community in turn typically focused on those aspects of their environment that affects them the most, *i.e.*, the infrastructure and townsite of Dawson.

The plan first inventories the current socio-economic and environmental characteristics of Dawson with the philosophy that future risk from climate change will stem from existing conditions in the community. The resulting local context forms the basis for a risk assessment of climate change impacts and consequences for the community. While some climate change impacts may be unprecedented, the uncertainty associated with these events reduced their response priority. Instead, known problems for which immediate response is justified were emphasized, as determined by an evaluation of existing conditions within the community.

The plan also includes a discussion on climate change in a regional context. The possible future conditions in Dawson are described based on an evaluation of projected local precipitation and temperature in the 2050s (*i.e.*, 2040-2070). The consequences of these shifts are then explored under the section *Dawson Community Impacts Scenario*. This narrative scenario was developed collaboratively with Dawson residents and is grounded in the local residents' knowledge of their environment. The consequences of climate change for the community, *i.e.*, the climate-induced vulnerabilities and opportunities, are derived from this local knowledge base. Each consequence noted in this section is evaluated based on the risk management strategy developed by the Dawson project team to determine where priority actions are required. A summary of these priority actions is included in the plan and suggests a timetable for implementation. The plan concludes with a discussion of next steps for increasing the adaptive capacity of the community of Dawson.

The project team responsible for developing the adaptation plan collaboratively with the community of Dawson is comprised of key members of the International Polar Year Dawson Community Adaptation and Vulnerability in Arctic Regions (CAVIAR)[1] team, the Northern Climate ExChange (NCE) Dawson Local Adaptation Coordinator, and the NCE Community Adaptation Project Manager.

PROCESS

From May 2008 to June 2009 the Dawson Adaptation Project Team worked with community representatives to explore regional vulnerabilities and assess local priorities (Figure 2). Collaboration between the project team and Dawson residents was underscored from the beginning. Local guidance in the development of this plan was provided by the Dawson Local Advisory Committee, which included representatives from the Conservation Klondike Society, government of the Tr'ondëk Hwëch'in and the City of Dawson. Membership of the Local Advisory Committee was determined based on those community stakeholders perceived to be vulnerable to climate change at the beginning of the planning process. Due to the community nature of the planning process, Yukon government voluntarily chose not to participate. The primary role of the Local Advisory Committee was to ensure community priorities were reflected in the planning process and to provide guidance on the planning process itself.

Initially, adaptation planning was directed by a perceived need to increase community resilience to climate change. Community resilience has been defined here as "…the capability of a system to maintain its functions and structure in the face of internal and external change and to degrade gracefully when it must." (Allenby and Fink, 2005, p. 1034). Resilience is important for ensuring that communities can withstand or recover from any negative consequence of climate change.

1. Dawson CAVIAR is funded by the International Polar Year and examines the following criteria: 1) establishing how local populations respond or adapt to stresses; 2) identifying the way in which the environment of the region may change in the future; and 3) assessing the capacity of the community to respond to these anticipated events.

To effectively plan for a resilient community, the project team developed and implemented a risk management strategy. The movement toward risk management was brought about by the organic approach to planning used in the development of the Dawson adaptation plan. Organic planning is an informal technique for planning during which the project team creates their framework as they move from milestone to milestone and respond to challenges. An organic approach was used for planning in Dawson because of the multitude of adaptation planning frameworks available, our focus on adaptive capacity, and the specific needs of the community. Organic planning was also found to be successful in the development of the Hall Beach, Nunavut climate change adaptation plan (BBE&DGI, 2008), which may indicate the utility of organic approaches for future adaptation planning elsewhere in northern communities. The risk management process that ultimately evolved does resemble other risk management strategies, in particular that proposed by the Australian Greenhouse Office (AGO, 2006).

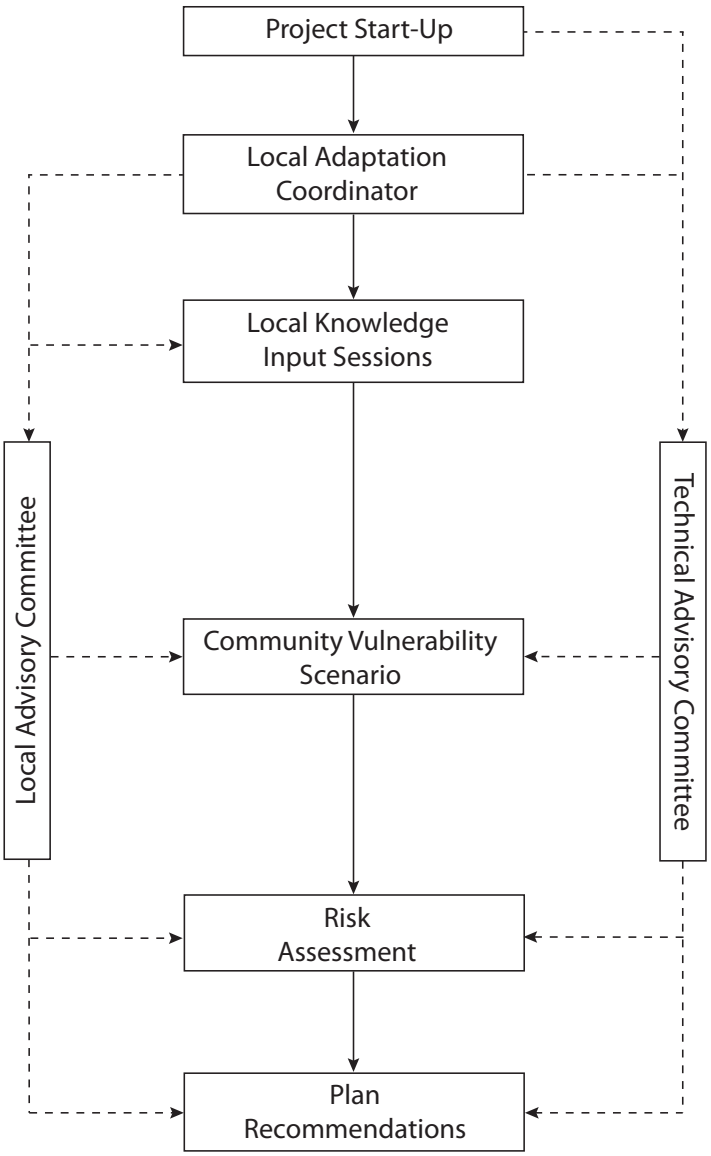

Figure 2. *Dawson Climate Change Adaptation planning process.*

During the first component of the planning process, the project team worked collaboratively with the community to develop a community vulnerability scenario. Community knowledge of how climate change may affect them was incorporated into the planning process through a number of open houses, individual interviews completed through the Dawson CAVIAR project, and through community input sessions that brought local experts together to discuss the implications of climate change in the community. The resulting community vulnerability scenario was then enhanced by a second workshop with the a Technical Advisory Committee composed of government and academic experts from outside the community, and which sought to reinforce local findings through the integration of scientific/expert knowledge. Members of the Dawson Local Advisory Committee and the Technical Advisory Committee are acknowledged in Appendix A.

In the second component of the planning process, the project team worked with the Local Advisory Committee to distill the community vulnerability scenario into a list of consequences that climate change may have for residents. Each consequence was evaluated based on a risk assessment framework. The risk assessment evaluates the consequences of climate change based on three predetermined characteristics of resilience: 1) the adaptive capacity of the community to respond to each consequence; 2) the level of event associated with the consequence; 3) and the likelihood of the event. Priorities were determined based on the relative ranking of each consequence. Details of the risk assessment methodology are provided in the section *Climate-Induced Vulnerabilities and Opportunities*.

DAWSON ADAPTATION PLAN VISION AND KEY CONSIDERATIONS

Several key considerations were identified that would define and bound the organic planning process. These key considerations were in part inspired from adaptation planning frameworks developed in the United States (for example, see Snover *et al.*, 2007) and in part by the input of the Dawson Local Advisory Committee into planning. Once the key considerations were established, the committee was asked to articulate a vision of a community that has successfully adapted to climate change. The vision statement guided the evaluation of possible adaptations by the project team and set the tone for the plan recommendations. The Dawson Local Advisory Committee vision of a successfully adapted community is:

> *Dawson City and its hinterlands will be a self-sustaining society, a community that lives within the limits of the local ecosystem and serves as a haven for its residents in an uncertain world.*

It will achieve this by:

- taking steps to increase its resilience;
- actively promoting self-sufficiency;
- increasing our knowledge of the environment around us; and
- developing ways to adapt to sudden changes in society and the climate.

The key considerations which drove the community vision are discussed below.

Assessing the Vulnerability of the Community to Climate Change

By determining where the community is most vulnerable to change, those events or impacts that carry the most immediate threat to residents can be identified and responded to through adaptation. Reducing community vulnerability is a key component of mitigating the environmental and socio-economic stresses created by climate change (Keim, 2008).

The Dawson Adaptation Plan seeks to prioritize adaptive responses to reduce community vulnerability to climate change.

Enhancing the Adaptive Capacity of the Community

The vulnerability of residents is influenced by the extent that the community is able to respond or the adaptive capacity of the community. Specifically, residents will be more vulnerable to impacts if they do not have the resources, information and expertise to respond to the environmental stresses that will accompany changing climate conditions. The objective of the Dawson Adaptation Plan is to enhance the adaptive capacity of Dawson by identifying where it is currently ranked as low and by providing recommendations on how the adaptive capacity can be increased to respond to future change and vulnerabilities.

Identify and Assess Any Potential Opportunities that may Emerge for the Community

Dawson may benefit from changing climate conditions. These opportunities may be economic or health related, and be generated by longer, warmer summers and shoulder seasons, and a more productive climate. The Dawson adaptation plan can establish the basis for a firm strategy that enables the Dawson community to gain from shifting climate conditions.

Avoiding Maladaptation

Maladaptation occurs when an action increases the vulnerability of the community (IPCC, 2007b). Careful consideration has been given to ensuring that plan recommendations will avoid the allocation of limited resources to actions that are ineffective and/or have no benefit for residents. The carbon footprint of recommended adaptations has also been considered as a component of maladaptation to ensure that suggested actions do not contribute to the onset or severity of climate change.

Emphasizing a Sustainable Community

Briefly stated, sustainable development and climate change adaptation can reinforce one another positively or negatively (IPCC, 2007b). The reasons for this are numerous, but of greatest importance in this context is the evidence that the socio-economic activities of a community can worsen the effects of climate change and vice-versa (Fraser, 2007). As a result, proposed adaptations seek to reinforce the principles of sustainability as they have been interpreted in *After the Gold Rush: the Tr'ondëk Hwëch'in and City of Dawson Integrated Community Sustainability Plan* (see TH&COD, 2008).

LIMITS OF THE DAWSON ADAPTATION PLAN

Vulnerability assessments should consider existing knowledge about the local environment and the socio-economic activities of the humans that reside within them to determine where a community is sensitive to change and how resilient residents are to the consequences of that change (Malone and Brenkert, 2008). The Dawson Adaptation Plan has endeavoured to compile information about the current state of the environment and socio-economic characteristics of Dawson. Plan recommendations are based on available information at the time of investigation. While academic literature was examined during the planning process, this was intended to support and substantiate the community vulnerability scenario rather than to generate an extensive literature review. The result is that local knowledge is placed at the forefront of the planning process. The emphasis on local knowledge was made possible by the close partnership between this project and the Dawson CAVIAR project, which functionally acts as an academic sister study. In addition, while some regional issues are touched on in the planning document,

these are discussed in keeping with the established context of community consequences. Therefore, regional issues are only assessed within a context of their impact on residents rather than in their own right.

A high degree of uncertainty is also a normal characteristic of climate change research (Malone and Brenkert, 2008), and is an integral component of the adaptation planning process. While uncertainty has been integrated into the framework used to develop this report, the recommendations of this plan should be revisited regularly as new information becomes available. As information becomes available, the uncertainty of how climate change will influence the community of Dawson will be reduced and may change the identified priorities. In other words, to ensure that the vision of the plan is being realized and that the proposed timeline is accurate, this adaptation plan should be updated regularly.

The mitigation of climate change was considered peripherally in the preparation of this report. Although a balance between the mitigation of, and the adaptation to, changing climate conditions is the most effective way to respond to the vulnerabilities reported here (IPCC, 2007b), planning for the mitigation of climate change was not included in this report as it was previously completed in the 2006 Dawson Climate Change Action Plan. Where possible, the action plan recommendations and those of this report should be considered together.

COMMUNITY PROFILE

The distinctive biophysical and socio-economic characteristics of Dawson are fundamental to the adaptive capacity of the community. A detailed community profile has been compiled in this section to describe the context in which vulnerability to climate change may arise and to provide a solid foundation for the risk assessment. In addition to the community profile, a history of climate-related stresses is provided on the assumption that Dawson residents will have a higher adaptive capacity to respond to stresses that they are familiar with.

SOCIO-ECONOMIC CHARACTERISTICS

The effects of the 1896 Gold Rush and subsequent influx of immigrants from around the world irreversibly changed the landscape and people of Dawson. The current demographic profile of Dawson is characterized by a number of features important for establishing the adaptive capacity of the community. The 2006 census notes the total population of Dawson to be 1,327, growing from a population of 1,251 in 2001. It should be noted that the census region for Dawson is limited to the municipal limits. As a result, a number of residents in the hinterlands of the community are not enumerated, *i.e.*, those residents living in West Dawson, Sunnydale, Rock Creek and other rural properties. These residents are enumerated as 'Yukon Unorganized'. The census date, 16 May 2006, also misses a substantial seasonal population composed of non-winter residents and seasonal workers. For example, the Yukon Bureau of Statistics estimated the health care population to be 1,793 in the second quarter of 2006 and rising to 1,923 by December 2008. While the census data does not account for every resident in the community, it does capture a sufficient bulk of the population to be representative of the community.

The population of Dawson is characterized by a relatively youthful population and has few children and elderly residents. Statistics Canada reports a ratio of 114 males for every 100 females. The community is also characterized by a high proportion of singles and one-person households. Most Dawson dwellings are single detached homes and many require major repairs. There are a small number of international immigrants; few of these are recent immigrants and most immigrated before 1991. Similarly, most of the population is at least third generation.

Tr'ondëk Hwëch'in citizens make up a high proportion of the population, but otherwise there is limited ethnic diversity.

The Dawson area has long been home to the Tr'ondëk Hwëch'in. The Tr'ondëk Hwëch'in Lands Department reported 338 First Nations citizens in 2009 (D. Anderson, Tr'ondëk Hwëch'in Lands and Resources Department, pers. comm., 2009). Of these citizens, 183 are male and 155 are female. Forty-seven percent of the First Nation population is under the age of 30, 47% of the population is between 31 and 64, and 6% is over the age of 65.

Dawson also has a relatively mobile population, which tends to move within the same municipality or make intra-territorial moves, or moves to neighbouring provinces; few are international migrants. While the significant transient population does provide distinctive characteristics to the community, the variable population has important implications for vulnerability and adaptive capacity. Transient members of the population tend not to have the same commitment to place (*i.e.*, Dawson) that permanent residents will have. As a result, if climate conditions have a negative influence on place, some members of the community may be more willing to abandon Dawson than others.

Mining has always played a prominent role in the local economy, and after a period of varying fortunes over the 20th century, it is now characterized by seasonal placer and hardrock mining and exploration. A tourism industry has also developed in the last few decades and key attractions include an impressive inventory of heritage buildings from the gold rush days that have been renovated and maintained by the Federal Government. Other attractions include tours at a nearby Parks Canada owned and maintained historic placer mining dredge, gold panning opportunities, long hours of summer daylight, northern lights (*aurora borealis*), 'traditional' dancing and gambling halls and bars, back-country tours, and ferry access to the 'Top of the World Highway' en route to Alaska. Traditional dirt roads and boardwalks also remain. Much transportation is by environmentally friendly means such as walking or cycling, but there is no opportunity for public transit use. Tourism is mostly restricted to summer months. Most tourists to Dawson originate from southern Canada, the USA and Europe. Although very seasonal in character (most tourist facilities are closed in winter), there are a few winter attractions, notably the Yukon Quest, a dog sled race between Fairbanks, Alaska and Whitehorse, Yukon.

Occupational groups are not diverse in Dawson. Employment consists mainly of resource-based industries, services, management occupations and trades, as well as transport and equipment operators and related occupations. College education tends to be valued to a greater extent among residents than university education, especially for older adults. Dawson has a high unemployment rate, particularly for males. Income is high compared to the rest of Canada, but low compared to the Yukon as a whole.

The Federal and Yukon governments are important employers in the town, which has a school, a branch of Yukon College, an RCMP detachment, Service Yukon facilities, Client Services for the mining industry, a Fish and Wildlife office, a YESAB office, EMS services, Yukon and NWT tourism centres, and, as noted, sizeable federal government-maintained tourism attractions. Tr'ondëk Hwëch'in also has a substantial presence in the community and has offices and facilities located in the Dawson downtown core. There is a local airport south of the townsite and seasonal ferry service across the Yukon River to the hinterland communities of West Dawson and Sunnydale. The ferry service and winter ice bridge also provides the only connection to the Top of the World Highway, the only access route out of the community aside from the Klondike Highway. It is evident that the economic basis of the town is vulnerable with a high degree of government

employment and investment, limited local demand, and a high dependence on two global industries characterized by volatile demand and prices: tourism and mining.

BIOPHYSICAL ATTRIBUTES

Dawson is located on a small flood plain at the confluence of the Klondike and Yukon rivers, near the Arctic Circle at 64˚04' N, 139˚26' W. The community is close to the boundary of two distinct ecological zones: the boundary of the discontinuous/continuous permafrost zones and within the boundary of the taiga/boreal ecozones (Smith *et al.*, 2004). Landscape characteristics of the Dawson region are further influenced by the Tombstone Mountains that frequently stop shallow outflows of cold arctic air, generating a relatively balmy microclimate (Smith *et al.*, 2004). The landscape of the Dawson region is characterized by its forest composition, discontinuous permafrost distribution, the local flood regime, local land uses (farming, trapping, hunting and fishing), and its location within the ancient landscape of Beringia.

Beringia is the unglaciated land mass that formerly provided a land bridge across the Bering Strait between 12.8 Ka and 11.3 Ka BP (Hoffecker and Elias, 2007). Because the area was unglaciated, the landscape is well weathered, thus promoting more extensive soil development. As a result, the soil is more fertile compared to those soils found in unglaciated areas of Yukon such as the more populated region around Whitehorse. Landforms in the region are characterized by large, unglaciated plateaus, containing deeply incised valleys and rolling hills. The area is somewhat unique as it still contains some relic flora and fauna from pre-glacial times that do not exist elsewhere in Yukon.

The most common species of trees found in the Dawson region are white spruce (*Picea glauca)*, black spruce (*Picea mariana*), trembling aspen (*Populus tremuloides*), paper birch (*Betula papyrifera*) and balsam poplar (*Populus balsamifera*). While lodgepole pine (*Pinus contorta*) can be found in the area around Dawson, it is at the northern limit of its range in North America. A unique feature found in the Dawson area is a combination of grasslands on south-facing slopes and boreal forest on north-facing slopes of the same hill. Lightning strikes occur with the greatest frequency in Dawson compared to the rest of Yukon, and the lowland forests burn and regenerate in cycles as short as 60 years. The tree line is typically found at an elevation of 1000 m above sea level (Smith *et al.*, 2004)

Dawson is located at the northern limit of the discontinuous permafrost zone. Permafrost is up to 60 m thick under the townsite and is close to surface. One exception where permafrost is deeper occurs where the soils are well drained such as where the Klondike River has deposited sand and gravel over an area located approximately 200 m inland from its present-day bank (Synergy West Ltd., 1975). Over the past century, the distribution of permafrost around Dawson has been heavily influenced by the mining industry, whereby permafrost was thawed and destroyed through the process of hydraulic mining or the stripping of overburden. Monitoring of the permafrost began in 2007 and more time is required to gather sufficient data before any trends can be determined; however, recent data revealed a permafrost temperature of approximately -1°C (C. Burn, Carleton University, pers. comm., 2009).

Dawson is subject to flooding in the spring. Regional flooding along the Yukon and Klondike rivers near Dawson occurs as a consequence of snow melt or ice jamming. Moderate flood waters generated by snow melt can reach 0.5 m and 1.0 m above the flood line, and there is a return period of 20 to 50 years respectively. Ice jamming can cause severe flooding and water levels may reach up to 3 m above the flood line. Floods of this magnitude are anticipated to have

a return period of 50-100 years (Janowicz, 2002). After a major flood in 1979, a dyke was raised to the point that the community is now considered safe from a 200-year flood[2].

Climatic data from Dawson indicates a frost-free period of greater than 80 days, a vegetative period in excess of 110 days and an average number of growing degree days[3] greater than 1200 (Smith *et al.*, 2004). When factoring in the availability of irrigation water from the rivers, and the high quality of the top soil, this region has the best agricultural possibilities in Yukon (Synergy West Ltd., 1975; Tarnocai *et al.*, 1988). There is market gardening at 9 Mile Island on the Yukon River, and in the Henderson's Corner area on the Klondike River. There are extensive agricultural lands in the Sunnydale area although they are not farmed intensively.

Trapping is an important, if irregular, land use in Dawson and trapping concessions are distributed around the region. Lands within approximately 8 km of Dawson are reserved for Tr'ondëk Hwëch'in Elders. The most significant species for trapping are: marten (*Martes americana*), lynx (*Lynx canadensis)*, wolf (*Canis lupis*), wolverine (*Gulo gulo*), fox (*Vulpes vulpes*), and some beaver (*Castor canadensis*) and mink (*Mustela vison*). Hunting is another land use that provides an important source of food for residents. Moose (*Alces alces*) is the main species hunted, followed by caribou (*Rangifer tarandus*), and Fannin's sheep and Dall's sheep (*Ovis dalli*). Most hunting takes place in August, September and October, primarily along the local roads and rivers.

In summer and fall, chum (*Oncorhynchus keta*) and chinook (*O. tshawytscha*) salmon ascend the Yukon River to their spawning grounds. Salmon fisheries, a feature of the region dating back to prehistory, harvest salmon in gill nets and fish wheels along the Yukon River near Dawson. A part of the annual harvest is used for subsistence food consumption by humans or as dog food. Salmon caught in the Yukon River, to a limited extent, are also sold locally to residents in the community. Other fish species found in the Yukon River include: lake whitefish (*Coregonus clupeaformis*), broad whitefish (*C. nasus*), round whitefish (*Prosopium cylindraceum*), inconnu (*Stenodus leucichthys nelma*), least cisco (*C. sardinella*), arctic cisco (*C. autumnalis*), bering cisco (*C. laurettae*), northern pike (*Esox lucius*), arctic grayling (*Thymallus arcticus arcticus*), burbot (*Lota lota*), longnose suckers (*Catostomus catostomus*), slimy sculpin (*Cottus cognatus*), arctic lamprey (*Lampetra camtschatica*) and lake chub (*Couesius plumbeus*).

There are several species sensitive to disturbance in the landscape around Dawson. The Species at Risk Public Registry recognizes four species found in the Dawson region listed on the Species at Risk Act (SARA); these species are listed in Table 1. Only those species legally recognized by SARA have been listed. The fact that other species considered threatened are present in the Dawson region should be noted[4].

2. The term "200-year flood" is used to describe the recurrence interval of floods. "100-year recurrence interval" means that the probability that a river will flow as high as the 100-year flood line in any given year is 1 in 100. Statistically speaking, each year begins with the same 1% chance that a 100-year event will occur. However, just because a 100-year flood happened last year does not mean that it will not happen this year since future rainfall and floods do not depend on the rainfall and floods that happened in the past. Past records are mainly used to show what kind of river flows can be expected (USGS, 2009).

3. Growing degree days (GDD) are used to estimate the growth and development of plants and insects during the growing season. The basic assumption is that development will only occur if the air temperature exceeds some minimum developmental threshold or base temperature. A linear increase in development is assumed if there is an increase in temperature or heat energy accumulation. The base temperatures are different for each organism. (OMAFRA, 2009).

4. For example, those species considered threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; http://www.cosewic.gc.ca/eng/sct0/rpt/dsp_booklet_e.htm).

Fifteen rare plant species are also found in the Dawson region. These species are rare, either globally or nationally, and include a number of species endemic to Beringia (B. Bennett, Department of Environment, pers. comm., 2009); rare plant species found in the Dawson region are provided in Table 2.

Table 1. Species listed on the Species at Risk Act (SARA) public registry.

Scientific Name	Common Name	SARA Listing
Euphagus carolinus	rusty blackbird	special concern
Asio flammeus	short-eared owl	special concern
Rangifer tarandus caribou	woodland caribou	special concern
Falco peregrinus anatum	peregrine falcon	threatened

Table 2. Rare plant species in the Dawson region (B. Bennett, Department of Environment, pers. comm., 2009).

Scientific Name	Common Name	Distribution
Corispermum ochotense Ignatov var. alaskanum	Russian bugseed	annual plant of Yukon River
Claytonia ogilviensis	Ogilvie Mountain springbeauty	found in 3 sites globally
Cypripedium guttatum swartz	pink lady slipper	rare in Canada
Silene williamsii	William's campion	endemic to Yukon and Alaska
Stellaria dicranoides	matted starwort	rare in Canada
Anemone multiceps	Porcupine River thimbleweed	Beringian endemic
Draba murrayi	Murray's whitlow grass	rare in Canada
Erysimum angustatum Rydb.	sand dune wallflower	Beringian endemic
Minuarita yukonensis	Yukon stichwort	globally rare
Saxifraga eschscholtzii	cushion saxifrage	Beringian endemic
Saxifraga spicata	spiked saxifrage	historic; may be extinct in Canada; known only from the Indian River
Viola biflora	arctic yellow violet	rare Beringian endemic
Podistera yukonensis	Yukon woodroot	endemic to Yukon and Alaska
Phacelia mollis Macbride	Macbride's Phacelia	endemic to Yukon and Alaska
Eritrichium splendens	showy forget-me-not	Beringian endemic

HISTORY OF ENVIRONMENTAL STRESSES

A review of historical environmental stresses served to establish the community's long-term exposure to these events, including how they responded and how they coped. This information was used by the project team to measure the adaptive capacity of the community. Historic environmental stresses were also used to assess the risk associated with a given consequence. While stresses stemming from climate change may evolve in a non-linear fashion, for the purposes of this report we have assumed that historic stresses are more certain to be of concern than new stresses evolving in the landscape. It should be noted that new stresses will carry a greater potential for destruction, and monitoring for the emergence of new risks should

be ongoing. Evidence of historic environmental stresses in the Klondike region was drawn from published material, from newspaper content analysis, and to a much lesser extent, from interviews.

Dawson residents have dealt with a range of environmental stresses since the founding of the community. These environmental stresses have arisen from natural and/or human sources. With respect to human activities, the Klondike gold rush resulted in extensive de-forestation (with subsequent implications for ecosystem health), water diversions (affecting fish habitat), and excessive wildlife harvesting to feed the early mining population of Dawson. Natural disruptions include spring flooding, forest fires, permafrost degradation, periodic shifts in the freeze-thaw cycle of the Yukon River, and shifts in the availability of fish and wildlife.

Historically, floods of various magnitudes have been a reoccurring problem, and the historic response was to live with the threat and bear the costs of any associated damage. A major flood in 1979 resulted in approximately $28M of damage[5] - a very high cost for a community of less than 2,000 people. The response was the construction of a dyke along the banks of the Yukon and Klondike rivers.

The forest fire record indicates consistent annual forest fire activity in the greater Dawson region, and over the last fifty years relatively few areas have been untouched by fire. Over time, it appears that the incidence of fire has increased. Although it may be tempting to correlate this with climate change, there are other factors that may be influencing this change, such as the increase in human activity in the surrounding region. McCoy (2002) confirms that overall the incidence of forest fires increased over the period between 1980 and 2000. Forest fires threatening the community are typically managed through a selective fire-fighting strategy. In Dawson, fire severity is managed proactively through the implementation of the FireSmart program.

Given that Dawson is located on what can be characterized as frozen swamp, historic permafrost-related problems are reflected in historic building practices and the exchange of heat between built-form and the underlying surface. Surprisingly, much remains unknown about the characteristics of permafrost around Dawson and sophisticated scientific endeavours to establish trends are relatively young. While some recent research suggests that permafrost in the region is resilient, there is growing evidence to suggest that the permafrost may be more vulnerable than previously thought (T. Lewkowicz, University of Ottawa, pers. comm., 2009). Responses to permafrost degradation include building code regulations, placing buildings on gravel pads and the use of thermosyphons.

An annual record on the freeze-thaw cycle of the Yukon River has been maintained since the end of the nineteenth century. The cycle had a major impact on the pace of life in Dawson in the past because the river cannot be traversed during freeze-up or break-up. Freeze-up on the Yukon River typically occurs in mid-November, while break-up usually happens in early May. The freeze-thaw cycle is problematic today because of the population growth on the western bank of the Yukon River. It is evident from interviews and workshops that the Yukon River is freezing later in the season, and the shoulder seasons (when the river is impassable) are lengthening. Statistical analysis does tend to support these observations, but they can also be interpreted as being within the tolerance of the range of the 100+ year record. A cable car across the Yukon River was made possible by Cassiar Asbestos Corporation Ltd. who owned and operated the Clinton Creek asbestos mine, ~100 km northwest of Dawson, between 1967 and 1978. The cable car allowed travel across the Yukon River during the shoulder seasons when the river was impassable. Today

5. Adjusted to current (2009) dollar values.

the normal response is for households to stockpile necessities; also the internet provides some residents of West Dawson with the ability to work from home.

Historically, wildlife shifts in the Dawson region have resulted from human activity (namely, the Klondike Gold Rush) and ecological cycles. For example, there has been a significant decline in the population of the Forty Mile caribou herd. Another ongoing concern is a decline in the Yukon River salmon run, which has resulted in a moratorium on commercial fishing and a reduction in the allowable First Nation food harvest. In fact, even in bad years such as 2009, there is limited commercial fishing. Fishery management is a difficult issue because salmon entering Yukon must first pass through Alaska, and the extent to which the decline in the salmon run is attributable to changing conditions in the north Pacific is debatable. However, there is evidence that climate change is a contributory factor to the declines that were primarily brought on by overfishing (Downtown and Miller, 1998).

Dawson has a long history of adapting to environmental stress and emergencies. Because of the relative isolation of Dawson and the experience that the community has had with dealing with acts of nature, residents have a general sense that they live with ongoing environmental stress and have adopted an attitude that they can cope with future challenges. The population boasts a wide range of skills, from traditional land-based skills to engineering and geo-technology.

SUSTAINABLE DEVELOPMENT IN DAWSON

Sustainable development is intimately linked with climate change and adaptation, and the development of adaptive capacity can influence the pace and character of sustainable development and vice versa. An equitable distribution of community resources, increased community capacity through education and skill development, and institutional support to help compensate for uncertainty are all common goals attributed to climate change adaptation programs and sustainable development (IPCC, 2007b).

Common goals that exist between planning for sustainability and climate change adaptation evident in the Dawson sustainability plan (TH&COD, 2008) are:

- the efficient provision of social services;
- the provision of quality building stock;
- the assurance of maintaining infrastructure needs such as ensuring potable water though the renovation of wells, ensuring safe waste disposal in the Quigley land fill, and ensuring recreation through the completion of the local trail network;
- the recognition of the prominent role that country food plays in the community and for the Tr'ondëk Hwëch'in; and
- an update of the emergency plan for the community.

It is recommended (IPCC, 2007b) that climate change adaptations should encapsulate a broader development context that ensures the proper establishment of education, health and governance. The efforts to increase the adaptive capacity of Dawson recommended in this report are therefore intended to complement those of the Dawson ICSP.

PLANNING CONTEXT: THE CLIMATE OF DAWSON CITY

To establish a context for the community vulnerability scenario, projected climate changes in the Dawson region were investigated on behalf of NCE by the Pacific Climate Impacts Consortium (PCIC) in the summer and fall of 2008 (see Werner *et al.*, 2009). The results of the PCIC report

were then communicated to workshop and open house participants during Community Input Week in November 2008. Participants were then asked to work with facilitators to identify how they may be vulnerable to projected regional changes.

Dawson is located at the northwestern extent of the Central Yukon Basin climate region (Whal *et al.*, 1987) where temperature variations can range from -60°C in winter to +35°C in the summer, a potential difference of 95°C (Environment Canada, 2009). Mean annual precipitation for the region ranges from 300-400 mm, much of which falls in summer showers (Whal *et al.*, 1987). Climate change is expected to greatly alter these general characteristics and increase the vulnerability of residents to environmental impacts.

To create an appropriate context for the community vulnerability scenario, a summary of baseline climate conditions (1961-1990) and 50-year trends provided by PCIC are described first. The anticipated climate of Dawson (2041-2070) is then described (see Werner *et al.*, 2008).

PAST TRENDS AND CURRENT CLIMATE CONDITIONS

Historical trends for temperature, precipitation, and streamflow for Dawson and the surrounding area were analyzed to give some indication of how climate conditions are being affected locally (see Werner *et al.*, 2008). Although the current trends may not continue into the future as they are influenced by climate change, an analysis of these trends does illustrate that change has taken place in the Dawson region. The 1961-1990 baseline climatology for the region was correlated with the Parameter-elevation Regressions on Independent Slopes Model (PRISM) interpolated dataset and was compared to the averages for this period from the Adjusted Historical Canadian Climate Database (AHCCD) for three stations (see Werner *et al.*, 2008). The result is climate projections that have an increased resolution compared to that offered by General Climate Models (GCMs).

Baseline Annual Temperature 1961-1990

Dawson experienced an annual mean baseline temperature of -7.2°C to -1.2°C from 1961-1990. A lower temperature range of -11.2°C to -5.2°C was experienced in the northern extent of the region (Werner *et al.*, 2008).

Temperature trends were established from data gathered from two weather stations – Dawson A and Mayo A. These stations recorded an average annual mean temperature of -5.3°C and -3.6°C, respectively, for 1961-1990, which supports the established baseline (Werner *et al.*, 2008). Trend analysis revealed an increase in mean temperature of 6.2°C per century for Dawson A and 5.8°C per century for Mayo A for the 50-year interval from 1955-2004 (Werner *et al.*, 2008). For the Dawson A station, minimum temperatures (nighttime lows) increased faster than maximum temperatures (daytime highs) and show an increase of 7.2°C and 4.8°C per century, respectively (Werner *et al.*, 2008). At Mayo A, temperature increases were only slightly greater for nighttime lows compared with daytime highs and revealed increases of 6.0°C and 5.4°C per century, respectively (Werner *et al.*, 2008).

Baseline Annual Precipitation 1961-1990

An annual range of precipitation from 200 mm to 500 mm occurred in the Dawson region between 1961 and 1990. The northeastern part of the study area had higher precipitation, ranging from 400 mm to 800 mm per year during the same interval (Werner *et al.*, 2008).

Precipitation data was gathered from three weather stations, Dawson A, Mayo A and Pelly Ranch. Mean annual precipitation at each station was recorded as 412 mm, 372 mm and 316 mm respectively, which also supports the reported baseline (see Werner *et al.*, 2008). Local

trends in precipitation varied considerably from station to station. Dawson A indicated a 29% per century decline in precipitation over a 50-year interval (1955-2004). Rainfall declined at 26% per century, while snowfall had declined 31% per century (Werner *et al.*, 2008). Mayo A showed an increasing trend for precipitation of 27% per century from 1955-2004; rainfall increased by 13% per century and snowfall increased by 30% per century during this 50-year time period (Werner *et al.*, 2008). Pelly Ranch also showed a positive trend for 1955-2004 and had an increase in precipitation of 30% per century; however, rainfall (32% per century) increased more than snowfall (7% per century) for that period (Werner *et al.*, 2008). The Pelly Ranch and Mayo A stations are east and slightly south of Dawson A. These stations are also roughly 100 m higher in elevation than the Dawson A station.

A later review of trends for Dawson A by PCIC confirmed a decline in precipitation from 1955 to 2004. However, an increasing trend that corresponds to the trends observed at Pelly Ranch and Mayo A stations was measured from 1976 to 2004, although the magnitude of this trend is not as large. None of the trends were statistically significant. Additionally, Dawson A is missing data for 2002, 2003 and 2004 and metadata for the Dawson A station is limited. Therefore, the negative trend observed at this station has little weight.

Streamflow

Streamflow for Dawson City is dominated by snowmelt runoff. Additionally, some streams have a glacier melt component. Streamflow records were analyzed over three periods 1965-2006, 1975-2006 and 1985-2006 (see Werner *et al.*, 2008). Trends show increases in the streamflow of the Yukon River above the White River from November to April and decreases in the late summer (Werner *et al.*, 2008). This suggests that snowmelt could be occurring faster and earlier in the spring. Such early onset of snowmelt may result in reduced streamflow in the summer and fall. Greater evaporation may also be taking place under warmer conditions in these seasons (Werner *et al.*, 2008).

It is important to note that the trends listed above are influenced by the 'teleconnections' between large-scale circulation phenomena (Fleming *et al.*, 2006). Teleconnections are statistically significant recurring and persistent circulation patterns between two or more geographic areas (Hatzaki *et al.*, 2006). Specifically, the El Niño/Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) were investigated for their influence on temperature and precipitation in the Dawson region. A third large-scale circulation system, the Arctic Oscillation (AO), also likely influences streamflow, temperature and precipitation in the Dawson region. PDO is distinguished from ENSO by its long-lasting phases, usually persisting for 20 to 30 years, while typical ENSO events persist for 6 to 18 months (Mantua *et al.*, 1997). El Niño refers to a warm ENSO event. The effects of these large-scale oscillations will be super imposed on climate change in the future and will add variability to projected climate conditions. These events may also reinforce or cancel each other out in respect to their effects on the climate in Dawson, and could mask or enhance the underlying warming of the climate. Climate change may also modify the strengths and temporal variability of these oscillations.

PROJECTED CLIMATE CONDITIONS FOR THE DAWSON CITY REGION (2041-2070)

Projected changes to the climate of Dawson City were derived from the Canadian Regional Climate Model (CRCM) for the 2050s (*i.e.*, average for the time period 2041-2070). The CRCM builds on the results of GCMs by incorporating elevation, topography, and other physical and dynamic processes at an increased resolution of 45 km^2 (Werner *et al.*, 2008). Results from 15 Global Climate Models for the 2020s (*i.e.*, average for the time period 2011-2040), 2050s and 2080s (*i.e.*, average for the time period 2071-2100) were also integrated into project climate

conditions. For the benefit of exploring the spatial variation in climate change, run 4 from the CRCM4 with the A2 emissions scenario was provided (*i.e.,* if no change occurs to our global consumption of fossil fuels). Results are presented by comparing the changes from the 1961-1990 baseline for the 2050s (2041-2070) (see Werner *et al.*, 2008).

The projection data presented in this section must be qualified. The CRCM model used to produce the projected climate-change maps (see Werner *et al.*, 2008) is driven by the CGCM3, which tends to have warmer, wetter conditions when compared to other GCM models. There is also greater uncertainty with precipitation projections than temperature projections due to the large variability in precipitation over space and in time (Werner *et al.*, 2008). Information to support these projections is currently limited and the need to improve the uncertainty associated with climate change projections is ongoing.

Anticipated Temperature 2041-2070

A relatively uniform increase in annual temperature of 2.5°C to 3.5°C is projected for the 30-year time period (2041-2070) of the 2050s (Werner *et al.*, 2008). These projections fall within the range of 2.1°C to 3.5°C given by the 25th and 75th percentiles from 15 GCMs (Werner *et al.*, 2008).

Winter is expected to experience the greatest extent of warming of between 4°C and 6°C (Werner *et al.*, 2008). These are some of the largest projected increases in temperature for western North America (Rodenhuis *et al.*, 2007). Summer warming is projected to be between 1.5°C and 2.5°C (Werner *et al.*, 2008). For the most part, the CRCM projections fall within those provided for the area by the 15 GCMS driven by two emissions scenarios A2 and B1. The CRCM winter projections are slightly greater than the maximum projections for the GCM models of 5.3°C (Werner *et al.*, 2008).

Anticipated Annual Precipitation 2041-2070

Annual precipitation in the Dawson region is projected to increase by 10% to 40%, and drier conditions are expected to occur to the north and east of Dawson City (Werner *et al.*, 2008). Increases in precipitation are projected to be higher in winter than in summer. A 30% to 50% increase in winter precipitation is projected (Werner *et al.*, 2008). An increase of only 10% to 30% is projected for the summer months (Werner *et al.*, 2008).

While drought conditions are not currently projected, drought may be a potential vulnerability if precipitation does not increase sufficiently to match increasing temperatures. Under these circumstances, drought would result from increased evaporation, which would dry out the landscape (ACIA, 2005). Drought conditions may be exacerbated by the projected increases in potential evapotranspiration, which may result in water-stressed vegetation (ACIA, 2005).

DAWSON COMMUNITY IMPACTS SCENARIO

The following climate change impacts scenario was developed in collaboration with Dawson residents based on the regional climate projections provided by PCIC (see Werner *et al.*, 2008) at a Community Input Week held in November 2008. The scenario identifies how possible climate changes may create vulnerabilities in the community. To best reflect community input, the scenario is reported in full. The evaluation of possible consequences and the risks they may pose to the community is presented in the following section. Of the eleven climate-change vulnerabilities identified by the community, five affected the landscape and six affected residents directly. Some community vulnerability stemmed from natural sources and evolving landscape conditions, such as forest fire conditions. Other vulnerabilities emerged as a result of natural forcing on human systems, specifically on the infrastructure or socio-economic conditions in

Dawson. The impacts anticipated by the community were also characterized by a temporal component, and were either slow to evolve and requiring the cumulative action of many influences or quick to develop due to extreme events.

Impacts influencing the landscape included seasonal and weather changes, forest fires, flooding, changes to wildlife and biodiversity, and permafrost degradation. Changes to tourism and recreation, access to the community, water quality or the level of regional contamination, shifts in the behaviour or culture of residents, the health and employment of residents, and the local economy, were among those climate-induced changes that may affect the community. It is evident that there is significant overlap among the impacts, and several landscape factors may contribute to a vulnerability identified for residents. Once completed, the scenario was reviewed with the Technical Advisory Committee to reduce the influence of speculation on the narrative, to ensure nothing of importance had been overlooked, and to enhance the scenario through the integration of technical/scientific knowledge from outside the community. A list of participants attending the Community Input Week is provided in Appendix B.

ANTICIPATED LANDSCAPE-LEVEL CLIMATE CHANGE EVENTS

Five landscape-level climate change events are anticipated to affect the residents of Dawson. These events are expected to affect many aspects of the regional ecology and could result in a significant cumulative change to the landscape around Dawson. A summary of each identified climate change event is provided below.

Seasonal and Weather Changes

A number of vulnerabilities were identified stemming from shifts in the weather and the lengthening of seasons in Dawson. Shifting seasonal periods are anticipated to result in an increased variability in the local climate that will reduce the predictability of weather for residents. Increasingly unpredictable weather will have far-reaching impacts on community life. For example, changes in the break-up and freeze-up of the Yukon River would affect the periods where the ice bridge and ferry are available and may ultimately result in increased periods of isolation for residents of West Dawson and Sunnydale.

Weather changes are also expected to result in increased wind that will have seasonal impacts. There is concern that drier summers would force more dust into the air. In winter, increased wind coupled with a declining influence of thermal inversions may cause an increased wind chill.

Increased precipitation is also of concern. More snow in the winter would create an increased need for snow removal on roadways. Wet springs could negatively impact lambing. Wetter summers may contribute to flood risks. Wetter seasons may also present opportunities; for example, longer, wetter springs combined with a shifting frost-free season may result in a longer growing season and an increase in locally produced food.

Increasing precipitation and rising water levels in the White River from rapidly melting glaciers[6] may increase the annual number of weather-related emergencies. Changing hibernation periods, shifting ranges, and a longer growing season may result in bigger bears, thus posing more of a threat to humans when there are encounters. Hunting and gathering traditions within the community may be affected by warming temperatures since migration patterns may shift. The combined effect of these seasonal changes will lead to greater uncertainty for those on the land as those areas that were previously thought of as safe become less secure, especially out on the

6. While it is true that flows in glacial-dominated systems have been observed to increase over the last several decades, the glacially fed component of the Yukon River at Dawson is so small that such trends are not evident in the discharge record at Dawson (R. Janowicz, Department of Environment, Government of Yukon, pers. comm., 2009).

water where sudden storm events may prove dangerous. Increasing uncertainty associated with local climate conditions may also have a negative influence on tourism.

Warmer temperatures will likely lead to an increase in the frequency of thunder storms and lightning, melt glaciers and increase water levels, and may create unpredictable ice conditions that will affect river crossings and travel out on the land[7]. Hot, dry weather will increase the incidence and severity of forest fires. Longer ice-free seasons and hotter air will warm water, affecting salmon populations. A warmer climate may also force a poleward migration of species, resulting in the potential loss of established local species. This may lead to increased invasive species and increased competition with those animals that remain such as wolves and coyotes, and/or rodents and insects. Northern migration of some species could impact traditional hunting patterns.

Warming conditions may mean people will use more air-conditioning, which will increase summer living costs, but this may be offset by decreased heating costs in shoulder seasons. Thinner ice as a consequence of warmer winters and longer shoulder seasons will affect winter traffic across the Yukon River. Residents believe that this cycle is already changing, and there have been several instances whereby the ice bridge has been built in different locations to compensate for the thinner ice.

Several benefits were associated with warming conditions. Warmer climate conditions will yield a longer growing season, which may increase agricultural productivity. Warming conditions will also lead to a greater variety of crops that can be grown reliably, and also favours increased yields from local harvests. Mining may benefit from warming conditions, especially if warmer temperatures increase the length of the mining season. Building on these opportunities may present some challenges, such as the possibility of land-use conflicts between an increased demand for agriculture and other pursuits. Crop yields may be affected by the migration of new insect pests that have the potential to devastate existing crops. Unstable climate conditions may not favour those crops that are dependent on certain environmental conditions and may serve to limit the economic benefits of a longer, more productive growing season.

FOREST FIRES

Workshop participants and respondents to community interviews identified fires as a key concern. As summers are predicted to become warmer and drier, the number and magnitude of fires may increase. The predominance of wooden buildings and the presence of significant historical infrastructure make Dawson potentially vulnerable to local fires. Structural damage from fire is a particular concern in West Dawson because of limited access to fire service. Residents were also concerned that an increased risk from forest fire to residential areas would increase home insurance costs. Apart from damage, smoke from forest fires will affect human health, especially for those with respiratory illnesses. Business may suffer if fires create challenges in transporting goods to the community, or if tourism declines. In addition to affecting businesses, road closures will affect the safety of the community if there was ever a need to evacuate Dawson. Smoke from fires will also affect the arrival and departures of aircraft, including medevac.

7. Injuries due to accidents are the leading cause of death in Northern Canada. It is 3 times higher in the North than in the South, and 8 times greater among First Nations. As such, it is an important consideration when discussing adaptation. Increased freeze-thaw and uncertain ice conditions can specifically increase the need for resources allocated to injury prevention (specifically to prevent drowning/hypothermia, multiple drowning events (rescue related) and education and awareness; J. Butler-Walker, Arctic Health Research Network, pers. comm., 2009).

An increase in the incidence of forest fires would likely affect the biodiversity of the region, changing the forest composition, shifting natural cycles and reducing the amount of timber available for harvest. More frequent fires can have the effect of fundamentally altering the ecosystem from boreal forest to grassland; this raises the productive capacity of the land, although many indigenous species are not adapted to these conditions (C. Brown, University of Saskatchewan, pers. comm., 2009). Fire damage to vegetation may alter the availability of food for herbivores. For example, lichen loss due to forest fire could reduce the caribou range, especially for woodland caribou, and may take up to 8 years to recover. Fire, smoke and loss of biomass may disorient animals and shift migration patterns, patterns that will also be influenced by habitat lost to fires. As migration patterns shift, hunting and trapping will be affected as trails change and traditional food sources may be less accessible. Hunters and trappers may also be directly threatened by forest fires.

Ironically, a number of opportunities were determined to be associated with forest fires, such as increases in temporary employment as more fire fighters would be required, and the possibility of ecosystem tours of fire-devastated areas. Large forest fires promote abundant morel mushroom growth in the first year following a burn, providing harvesting opportunities for residents as well as economic opportunities for mushroom pickers.

Flooding

During community interviews, concerns with changing river conditions and flooding were very frequently mentioned. Dawson is located on a flood plain at the confluence of the Yukon and Klondike rivers and is therefore extremely susceptible to flooding. The vulnerability of residents may therefore be increased by the combined action of rising water levels in the river as a product of rising temperatures and changes in weather patterns. Flood risks include damage to buildings and personal property and the contamination of drinking water. Flooding may also increase bank erosion, changing the shape of the river, and over time, challenging the navigability of the river. Severe floods may be a threat to Parks Canada and other heritage sites, both within the townsite of Dawson and in its hinterland areas. Damage to heritage sites that are owned and operated by Parks Canada may have a subsequent effect on the tourism industry. Flood defences in Dawson (*i.e.*, the construction of the dyke) were thought by participants to have significantly changed the sense of place of the community by separating residents from the river. The effectiveness of the dyke system was also questioned, and some residents believe that if breached, the dyke will slow the movement of water out of the community, thus prolonging flood conditions. However, the same defences have increased the recreational opportunities for residents in the form of a trail system on top of the dyke.

Wildlife and Changes to Biodiversity

Shifting local climate conditions are expected to have a number of impacts on regional wildlife and biodiversity. In general, the timing and changes to migration patterns were of concern to workshop participants. These include birthing cycles no longer in sync with the seasons; rivers no longer frozen during migration periods; the displacement of old species as new species move poleward; and the resulting disorientation of animals. For example, shifting migration periods for insects may also have a detrimental impact on bird populations if the birds arrive before insect eggs hatch. Changes to fish abundance as river waters warm was another example of possible climate-related changes to biodiversity.

Residents were also concerned that wildlife would struggle to find food. Of particular importance was the Porcupine caribou herd, which may be challenged by shifting ice conditions that may affect their ability to migrate or find food. Impacts to the health of the Porcupine caribou

herd may have a ripple effect throughout ecosystems especially on predators and furbearers. Participants were also concerned that displaced or reduced populations may be slow to recover, having subsequent impacts to the ecological and socio-economic norms. It was suggested that over time, a change in hunting emphasis from caribou to northerly migrating elk and bison may be required.

Shifts in local flora are predicted to result in changes to local wildlife. Warming climate conditions may favour established invasive species, which have the potential to alter the local species mix. The local species mix may be further altered as the established vegetative norms shift and the treeline moves. For example, if the viability of white spruce species declines with warming climate conditions, there may be a subsequent impact on the ability of forests to recover from fires, and/or a decrease in the ability of forests to grow in hot summers. Invasive or rapidly increasing insect populations will also affect forest conditions as insect feeding cycles shift out of sync and damage the forest. In another example, changing blooming times may negatively affect some insect populations if this timing falls out of sync with insect feeding cycles.

Changes to wildlife and biodiversity will have an impact on the human population of Dawson. Declining populations of wildlife could result in less harvesting of traditional foods, resulting in subsequent impacts to the health of residents as they turn to store-bought foods. Subsequent health impacts may include an increased risk of obesity, diabetes and other chronic diseases. Currently most residents prefer hunting to animal husbandry. However, if traditional resources decline, this may change; and concern was expressed by residents that the possibility of new diseases spreading through remaining wildlife populations may increase as a result, especially if new species of domestic animals are introduced to the region.

Permafrost Degradation

Permafrost degradation has the potential to have a tremendous impact on the landscape of the Dawson region. An increasing depth of the active layer is already affecting infrastructure integrity. As the active layer deepens, ground subsidence may increasingly affect buildings and infrastructure. Participants also observed that positive drainage away from new developments will force water into new areas, thus further thawing permafrost. Failure in the water and sewer system could potentially become a public safety issue if sewers back up. Subsidence and slope failure created from more frequent freeze/thaw cycles may affect road and driving conditions, especially along the Klondike, Alaska and Dempster highways. Heritage buildings owned by Parks Canada were identified as especially vulnerable given the financial investment that was made for their restoration. These buildings will likely require additional costly restorations if permafrost continues to thaw. However, the processes of permafrost thaw in Dawson and the implications for infrastructure are not fully understood.

While permafrost thaw may create increased opportunities for mining by enhancing access to workable ground, degradation of roads and infrastructure will have a negative impact on mining. Likewise, potential damage to mining infrastructure and equipment may occur as ground conditions become unstable. Structural damage to tailing ponds and facilities historically dependent on permafrost may occur. It was reported that the possibility exists that working conditions may decline as frozen ground thaws and camps fill with ‘black muck’ (the pervasive, thick layer of black silt that covers most of the valley bottoms in the Klondike). Tourism may also decline as traveling conditions worsen and historic buildings increasingly succumb to ground instability. Gift shops, restaurants and hotels may all be affected both by dwindling business and increasing annual maintenance costs.

Slope failure associated with permafrost thaw has been observed to release sediment into rivers and streams. Subsequent increased turbidity in rivers will affect the habitat and spawning of valuable fish stocks such as salmon. Erosion will become worse as permafrost degradation affects the vegetative cover where soils become saturated. Shifting landscape conditions may also lead to an expansion of swamp with a subsequent increase in mosquitoes and other insects.

The possibility that permafrost would become a carbon source by releasing carbon dioxide and methane into the atmosphere was also of concern to participants. These greenhouse gases would exacerbate the onset of climate change in the North.

ANTICIPATED COMMUNITY-BASED CLIMATE-CHANGE VULNERABILITIES

Changes to the landscape due to climate change may result indirectly in a declining economy and poorer living conditions for residents, leading to a subsequent rise in social problems in the community. Residents also anticipate that a number of opportunities will arise from climate-change impacts. Given the community scope of this planning process, cascading or cumulative climate-change impacts affecting resource availability outside the study area are not considered in full. It is important to note that climate-change impacts to the power supply, food supply, health services available to residents, *etc.*, are influenced by the state of territorial and global markets and transportation. How climate change affects the world will exacerbate the anticipated community-based climate-change vulnerabilities listed below. The reported socio-economic opportunities and vulnerabilities arising from climate change are described in the following paragraphs.

Tourism and Recreation

Tourism was identified by participants as a potential climate change-induced opportunity. Warmer climate conditions are anticipated to have a positive influence by increasing the length of the tourism and recreation seasons in Dawson. Improved conditions for recreation such as the probability of better skiing as a result of increased snowfall were also noted. An extended tourism and recreation season will benefit tourism businesses and outfitters within the community. However, discussions revealed that these opportunities were highly dependent on access and would be subject to increased unpredictability of river navigation (*i.e.*, winter freeze-up and spring thaw), which could cause travel delays. More extreme weather events would also cause poor travel conditions. Challenges associated with covering the costs of new recreational opportunities if climate conditions shift dramatically were also raised as a limiting factor. Recreation was felt to be less vulnerable to negative climate influences due to the resilience of the 'local fabric' or the ability of residents to take advantage of sub-standard recreational opportunities.

Access

Transportation and infrastructure are two main concerns for the community and were both identified as areas that are vulnerable to climate change. Increasing disruptions along the North Klondike Highway and other transportation corridors may reduce access to Dawson as infrastructure and transportation are negatively affected by increased precipitation and permafrost thaw. Travel conditions at the airport are expected to deteriorate because of increased ice fog and increasing uncertainty in seasonal conditions. A decline in travel conditions has implications for the tourist industry and delivery of goods to Dawson, and may exacerbate the sense of remoteness of the community.

Water Quality and Contamination

Water quality is anticipated by participants to decline as warming conditions cause increased precipitation and surface run-off. Increased erosion stemming from a combination of increased surface run-off and permafrost degradation will have a detrimental impact on the quality of fish habitat. Similarly, increased sediment in rivers will increase the turbidity of the water and decrease water quality. A higher water table may increase the vulnerability of septic fields, which might lead to contaminated surface water and/or wells, threatening the local water supply.

Contaminated surface water may also be influenced by permafrost degradation, which will cause the emergence of new avenues for contaminants to enter water. The emergence of new avenues increases the unpredictability of future contamination. For example, glacial thaw may lead to the release of contaminants into drinking water that was formerly trapped by ice into drinking water, leading to a further uncertainty regarding what contaminants are entering the water supply. Landslides and erosion may also lead to the release of mercury as permafrost degrades. Abandoned and/or unknown waste sites may provide additional sources of contamination if affected by permafrost degradation. Contaminants may also leach out of the Quigley Solid Waste Facility, which is unlined. (M. Nefstead, Contaminated Sites Analyst, pers. comm., 2009). Contaminated water may lead to an increased consumption of bottled water, which is considered by participants to be undesirable. Increased surface run-off will also lead to an increase in the amount of silt washing into storm drain systems, further straining infrastructure.

Increased warming has direct implications for the health of residents by increasing the degree of dampness in old buildings. An increase in dampness will favour the development of mould growth within the buildings resulting in subsequent impacts on the health of residents. Given that people have varying tolerances to mould, only a slight shift in the presence of mould within old buildings may have severe implications for human health. Residents have already responded to the poor air quality in some of the buildings by moving their office locations. An increase in the rate of radon release may also occur with warming conditions. Accelerated bio-accumulation, and the build-up of PCBs and heavy metals in water and food, may occur with global warming and may result in local food sources that are unfit for consumption.

Behaviour and Cultural Shifts

Participants anticipate a number of shifts in the behaviour and culture of Dawson as a consequence of climate change. These shifts are tied to cutbacks in service provisions if the community becomes increasingly isolated by climate-change impacts and the cost of fuel escalates. A decrease in social opportunities due to these changes is further expected to increasingly isolate the more vulnerable members of the community. Many shifts are also anticipated to be positive, as the community knowledge base expands and there is an increase in local resilience. Positive changes in local behaviour are anticipated to grow with climate change, for example, the recent shift in the community from plastic to canvas grocery bags. Participants felt that a need exists to balance standards and ensure the health of the community while keeping the provision of health care affordable and sustainable.

Health, Employment and Well-Being

Existing stresses for residents of Dawson such as unemployment, anxiety, unhappiness and depression are anticipated to increase within the community. For example, more overcast skies due to increased precipitation could increase the incidence of SAD (Seasonal Affective Disorder). The indirect effects of climate change could also negatively impact the mental health of the community if an economic downturn occurs because of a decline in the local tourism industry. Residents believe that their physical health may also be impacted by shifts in consumption

patterns. For example, the methylation of inorganic mercury is biologically mediated, so increased temperature will increase the bio-availability of methylmercury. Employment concerns were ranked as very high in the community interviews. If economic opportunities decline, housing affordability will become an even more important issue. Construction costs may also be affected by increased shipping costs. Homes may become more hazardous if housing maintenance declines due to increased unaffordability.

Costs

Community interviews identified concerns about living costs and the possibility that household costs and seasonal budgets could change with warmer summers and shorter winters. When considered within the context of a reported shift in the community cultural economy from heritage conservation towards wilderness and arts, climate change may affect the sustainability of emerging activities. Properly scoped, participants identified increased local resilience as an opportunity to be generated from shifting climate conditions. For example, the ability of residents to respond to changes in both wildlife and agricultural shifts was seen as compromised by over-regulation of local food processing.

CLIMATE-INDUCED VULNERABILITIES AND OPPORTUNITIES

Based on the results of the community impacts scenario derived from the NCE Community Input Week and the Dawson CAVIAR study, climate change will have a number of impacts on the Dawson region. Few of these impacts are positive. Opportunities for residents may include an extended mining season, increased tourism opportunities, reduced winter fuel consumption and an increase in the resourcefulness and adaptability of the community.

The necessity for adaptation planning is driven by events which will have major impacts on Dawson's landscape. These include permafrost thaw, forest fires, flooding, changing precipitation patterns, and shifts in wildlife. Possible consequences for the Dawson region include compromised access, degradation of community utilities and damage to buildings, negative economic impacts, and pressures on traditional harvesting. The vulnerability of Dawson's hinterlands will also increase, and remote neighbourhoods such as West Dawson will likely experience greater periods of isolation as shoulder seasons lengthen and forest fire risks increase. An increased risk of damage to infrastructure due to climate-induced vulnerabilities will likely result in increased insurance costs. Rising costs may have a compounding effect on the anticipated rise in costs of maintaining infrastructure and buildings damaged by permafrost degredation. The physical and mental health of residents could also be negatively influenced by climate change as the community responds to an increased risk of water and food contamination, increased unemployment, stress, depression and anxiety.

The consequences of the climate change vulnerabilities identified in collaboration with the community are described below. Community vulnerabilities have been prioritized based on our established elements of risk, in keeping with the strategy proposed by AGO (2006). These risk elements are: the anticipated level of the impact, the likelihood of the impact, and the adaptive capacity of the community. Based on the resilience evaluation framework proposed by the project team, priority risks are characterized by a high level of impact, high likelihood that the impact will occur, and a low capacity observed in the community to respond. For the purposes of this assessment, the adaptive capacity of Dawson was evaluated based on four components: the familiarity of the impact, the resources available within the community with which to respond to the impact, the motivation of residents to respond to the impact (interpreted through place identity), and the level of education and skills required to effectively respond to the impact.

All possible climate-change adaptations proposed to address the consequences of climate change are listed at the end of each section. The majority of these responses were suggested by the community of Dawson during Community Input Week. The remainder were proposed by participants during the Technical Advisory Committee meeting. These adaptations are reported here in full. Because priority adaptations are characterized by a low capacity on the part of the community, a designated partner is suggested for each identified consequence. These partners are anticipated to be the most capable of providing support to the community for implementing the suggested actions. In many cases, more than one partner is suggested, reflecting that adaptation will occur at many levels in the community and over a long period of time in a complex manner, as observed by Berkes and Jolly (2001). For example, the suggested actions are both coping mechanisms (immediate and small-scale responses) and adaptive strategies (long-term responses). It should be noted that this is an evaluation of community capacity only and is not intended as an evaluation of the capacity of the designated partners. The capacity of identified partners to implement the suggested action may therefore also be low.

While partnerships between many levels of government and institutions will be more effective when implementing adaptations, for the purpose of simplicity, the partners suggested here have been limited to the various branches and departments of Yukon government, City of Dawson, Tr'ondëk Hwëch'in, and the Government of Canada. Where community level response is proactive and necessary, the suggested partner has been designated as 'community groups' in anticipation of volunteer action or actions by community members with the responsibility to do so. This includes the actions of local businesses and individuals. Recommended adaptations are provided in the section *Climate Change Adaptation and Dawson*.

REGIONAL VULNERABILITIES

Eleven regional, non community-based vulnerabilities were derived from the Dawson community impacts scenario. They have been reported because residents identified them as being of concern and because they occur within the defined study area boundary. However, despite the cumulative effects that the consequences may have on life in Dawson, all potential responses are beyond the scope of this plan. For consistency, we have maintained the vulnerability nomenclature under which the consequences were identified by residents.

List of regional vulnerabilities and related consequences.

Ref #	Vulnerability Type	Climate-Change Consequence
R.1	forest fire	• Increased frequency of forest fires alters the biodiversity of the region and shifts natural cycles. • Increased frequency of forest fires changes forest composition. • Loss of biomass shifts migration patterns. • Migration patterns shift when animals become disoriented by smoke or fire.
R.2		• Fire damage to vegetation alters the availability of food for herbivores.
R.3	wildlife and changes to biodiversity	• Viability of white spruce declines.
R.4		• Aspen leaf miners are favoured by climate change and increasingly exert a negative effect on individual aspen, thus reducing the proliferation of aspen.

List of regional vulnerabilities and related consequences, *continued.*

Ref #	Vulnerability Type	Climate-Change Consequence
R.5	wildlife and changes to biodiversity	• Displacement of old species occurs as new species move pole-ward. • Diffusion of invasive species populations occurs throughout region. • Established invasive species proliferate due to warming temperatures. • New invasive species are introduced through new agricultural experiments and land uses (*e.g.*, use of exotics to landscape the downtown core).
R.6		• Established vegetative norms shift as the treeline moves.
R.7		• Warming climate conditions favour established invasive species, altering local species mix.
R.8		• Changing blooming times negatively affect some insect populations as timings fall out of sync.
R.9		• Shifting climate conditions alter the hibernation period of trees and wildlife.
R.10	water quality and contamination	• Warming conditions exacerbate bio-accumulation (the build-up of PCBs and heavy metals in water and food) due to air circulation.
R.11	permafrost degradation	• Thawing permafrost becomes a carbon source, rather than functioning as a carbon sink.

Suggested Adaptations to Non Community-Based Vulnerabilities

Given the potentially extensive impact that regional vulnerabilities may have on the community and the poor understanding of how these risks may actually influence Dawson, all regional consequences have been ranked of high priority.

List of suggested adaptations to regional vulnerabilities.

Ref #	Priority	Lead Partners	Suggested Adaptations
R.1-R.11	High	all noted responsible authorities	• Test less invasive ways for studying wildlife (*e.g.*, salmon). • Initiate research and monitoring to reduce uncertainty, observe change, and evaluate possible impacts and responses. • Integrate such research and monitoring into existing networks*.
R.1,2,3, 5,6,8, 9,11		YLUPC	• Integrate a vulnerability assessment into regional land-use planning.

*Such as SAON, GEOSS, CBMP and those unique to the territorial government.

COMMUNITY-BASED CONSEQUENCES OF CLIMATE CHANGE

Fifty-two consequences of climate change were identified in the Dawson community scenario. Each consequence stems from climate-induced changes in regional flooding, forest fires, and weather. These changes may affect access, health, land use and the local economy. The

relative risk that the identified consequence poses to the community is then evaluated based on the characteristics of resilience proposed above: the level of impact, the likelihood of the consequence, and the adaptive capacity of the community to respond to the consequence. A high priority was assigned to consequences for which the level of impact and likelihood of the identified consequence was high and the adaptive capacity of the community was low. A high priority was also assigned if one or more of the risk assessment criteria were unknown. This is due to the evident need to increase the level of knowledge base associated with the consequence.

Flooding

Climate change may result in an increased risk for the community due to changes in weather patterns such as increased precipitation and/or incidence of freeze-thaw leading to increased frequency and severity of flooding (*e.g.*, spring ice-jamming in the Yukon River).

List of community consequences of flooding.

Ref #	Consequence	Community Resilience			Priority
		Level of Impact	Likelihood	Adaptive Capacity	
F.1	• Floods threaten Parks Canada/Heritage resources and other building stock. • Flooding may exceed the responses planned in the EMO limiting the availability of emergency services.	High	High	Low	High
F.2	• Planned site of sewage facility may be vulnerable to changing hydrological conditions such as flooding.	High	High	Low	High
F.3	• Septic field breaches are more likely as water table rises, which may lead to contaminated surface water and/or wells.	Low	High	High	Low
F.4	• Increased surface run-off generates infrastructure problems as silt clogs drains	Low	High	High	Low

List of suggested adaptations to climate-induced flooding.

Ref #	Priority	Lead Partner	Suggested Adaptations
F.1	High	Government of Yukon, City of Dawson, Tr'ondëk Hwëch'in	• Release information about possible flooding. • Investigate the need to raise the existing level of the dyke. • Determine who is responsible for the work. • Examine the flood risk for the Tr'ondëk Subdivision. • Update flood response plan. • Record local knowledge regarding seasonal flooding and vulnerabilities. • Maintain active monitoring during spring break-up.

List of suggested adaptations to climate-induced flooding, *continued.*

Ref #	Priority	Lead Partner	Suggested Adaptations
F.2	High	Government of Yukon	• Investigate the need to raise the existing level of the dyke and designate institutional responsibility. • Implement flood proofing of new facilities during the design process. • Sewage facility design needs to factor in how to prevent backups and how to discharge treated effluent under high-water regimes.
F.3	Low	Government of Yukon	• Implement a flood-risk and climate-change assessment. • Compile information from Yukon Energy and Yukon government that addresses shifts in streamflow and glacial melt.
F.4		City of Dawson	• Identify the drains that are most vulnerable to siltation and prioritize maintenance and response during floods.

Forest Fires

Increased incidence and severity of forest fires could result from warmer summer conditions leading to climate-induced consequences for Dawson residents.

List of community consequences of forest fires.

Ref #	Consequence	Community Resilience			Priority
		Level of Impact	Likelihood	Adaptive Capacity	
FF.1	• Extensive fire damage to relatively isolated areas such West Dawson and Sunnydale	High	Medium	High	Low
FF.2	• Smoke from fires inhibits evacuation and transportation (by road and by air), thus increasing isolation.	Medium	High	High	Low
FF.3	• Hunters, trappers and others using the landscape around Dawson are potentially threatened by forest fire.	Medium/ Low	Medium	High	Low
FF.4	• Potential threat to infrastructure in downtown Dawson from forest fire, including loss of wooden heritage buildings.	High	Medium/ Low	High	Low/ Medium
FF.5	• Increased frequency of forest fires reduces the amount of timber available for harvest as lumber, thus affecting local economy.	Medium	Medium	Medium/ Low	Medium

List of suggested adaptations to increased forest fire risk.

Ref #	Priority	Lead Partner	Suggested Adaptations
FF.5	Medium	Tr'ondëk Hwëch'in	• Review and support the forest adaptive management strategy being developed by the Dawson Renewable Resources Council. • Investigate methods to increase the salvage component of firekill wood harvest.
FF.4	Low/ Medium	Tr'ondëk Hwëch'in, City of Dawson	• Consider fire vulnerability when building new residences. • Review and update fire response plan, and provide more fire breaks.
FF.1	Low	Tr'ondëk Hwëch'in, Government of Yukon	• Complete FireSmart program. • Establish peripheral (*e.g.*, West Dawson) fire support. • Compile a literature review of possible impacts of forest fire on permafrost landscapes.
FF.2		City of Dawson, Government of Yukon	• Close road and air traffic as necessary. • Transport goods and people via convoys along the highway into the community during periods of impaired sight. • Review and update fire response plan. • Ensure two access routes into Dawson.
FF.3		Government of Yukon	• Improve fire defenses. • Increase communication and provide public education.

Seasonal Weather Changes

Increased variability in seasonal weather as a result of changing climate conditions may lead to reduced predictability of weather for residents, thus creating challenges for those on the land. Possible future changes include: an increase in the intensity of wind; drier summers forcing more dust into the air; and increased thunder storms and lighting due to warmer temperatures.

List of community consequences due to seasonal weather changes.

Ref #	Consequence	Community Resilience			Priority
		Level of Impact	Likelihood	Adaptive Capacity	
SW.1	• Increased incidence of extreme events characterized by high wind and precipitation leading to damage of property, infrastructure, and agriculture.	Medium/ High	High	Low	Medium/ High
SW.2	• Increased snowfall potentially leads to added isolation for some residents, and the need for snow removal in outlying areas.	Medium	Low/ Medium	High	Low
SW.3	• Increased snowfall negatively influences the performance of bituminous surface treatment (BST), resulting in potholes along highways.	Low	High	High	Low

List of community consequences due to seasonal weather changes, *continued.*

Ref #	Consequence	Community Resilience			Priority
		Level of Impact	Likelihood	Adaptive Capacity	
SW.4	• Longer shoulder seasons and warmer winter weather produce thin ice on the Yukon River resulting in unpredictable ice conditions for travel, and possibly leading to less access to trapping, and other winter recreation activities.	Medium	High	Medium/ High	Low/ Medium
SW.5	• Ice bridge is compromised due to warmer winter temperatures leading to increased periods of isolation for residents in West Dawson and Sunnydale.	Medium/ High	High	Medium	Medium/ High

List of suggested adaptations to increased risk from seasonal weather changes.

Ref #	Priority	Lead Partner	Suggested Adaptations
SW.1	Medium/ High	Tr'ondëk Hwëch'in, Government of Yukon	• Investigate the feasibility of a severe storm warning system. • Create emergency shelters. • Change building codes to compensate for seasonal weather changes. • Investigate the potential for drought conditions and its impacts on the Dawson region. • Identify an existing community with a similar population to Dawson and situated at a lower latitude, which could be used as a model for predicting potential climate-change impacts.
SW.5		City of Dawson, Government of Yukon	• Construct a helicopter pad for emergencies. • Increase household preparedness education. • Complete evacuation planning process.
SW.4	Low/ Medium	Tr'ondëk Hwëch'in, City of Dawson	• Document the collective experiences of the community as they relate to shifts in local weather patterns.
SW.2	Low	City of Dawson	• Increase preparedness education.
SW.3		Government of Yukon	• Ensure roads are kept clear during spring melt. • Investigate the performance of alternative road surfacing.

Permafrost Degradation

Warming climate conditions leads to the thawing of permafrost or increase in the active layer, which may lead to subsequent issues in the community.

List of community consequences of increased risk to permafrost degradation.

Ref #	Consequence	Community Resilience			Priority
		Level of Impact	Likelihood	Adaptive Capacity	
P.1	• Severe permafrost degredation forces the massive re-engineering of the town site.	High	Unknown	Low	High
P.2	• Ground subsidence affects buildings and creates negative impacts to Parks Canada/Heritage resources.	Medium/ High	High	High	Medium
P.3	• Failure in water and sewer system creates public safety issue.	High	High	High	Medium
P.4	• Road surface quality declines due to frost heaves, compounded by subsidence and slope failure related to permafrost thaw. • Risk of slope failure along adjacent sections of the highway extends the vulnerability beyond the highway proper.	High	High	Medium	High
P.5	• Increased turbidity in tributaries due to slope failures and erosion affects spawning habitat; these effects are compounded if permafrost thaws due to forest fire, or if permafrost degredation causes slope failures, which affects vegetative cover.	Medium	Medium/ High	Low	Medium
P.6	• Mining infrastructure (*e.g.*, roads) and equipment are threatened by ground instability.	Low	High	High	Low
P.7	• Deepening active layer affects infrastructure integrity and causes structural damage to tailings ponds.	Low	Medium	High	Low
P.8	• Condition of mining roads deteriorates as frozen ground thaws.	Low/ Medium	Medium/ High	High	Low
P.9	• Permafrost degredation causes leaching of contaminants from abandoned waste disposal sites.	Unknown	Unknown	Low	High
P.10	• Increased leaching of contaminants from the active and unlined Quigley Solid Waste Facility.	High	Unknown	Low	High

List of suggested adaptations to increased risk from permafrost degradation.

Ref #	Priority	Lead Partner	Suggested Adaptations
P.1	High	all noted partners	• A detailed permafrost assessment is required.
P.4		Government of Yukon, Government of Canada	• Continue vulnerability assessment and action planning (*e.g.*, build on experiences in and around Beaver Creek) and ensure resources are available to respond. • Change road materials - use stronger materials.
P.9			• Continue monitoring in the area for changes in water quality. • Complete a risk assessment that also inventories abandoned dump sites in the Dawson area. • Designate fiscal responsibility for site remediation.
P.10			• Provide monitoring in the area for changes in water quality. • Complete the hydro-geological testing of the Quigley Solid Waste Facility.
P.2	Medium	City of Dawson	• Ensure resources are available and response planning is in place. • Investigate how permafrost warms to 0°C through the establishment of a test site within the Dawson town site. • Reconsider lowest bid system and add a greater priority for quality. • Use different foundation materials and develop better building codes. • Develop seasonal recreation infrastructure (*e.g.*, low-tech hockey rinks) that is not vulnerable to permafrost degredation. • Determine the potential severity of permafrost thaw on Parks Canada buildings and relocate vulnerable buildings if necessary. • Explore the feasibility of using thermosyphons. • Use methods of travel that require less infrastructure such as smaller and less-traveled roads, and more foot and ski trails.
P.5		Tr'ondëk Hwëch'in	• Provide information on how to diversify diet (in a healthy manner).
P.3		City of Dawson	• Test ground and inventory infrastructure and compile a map of vulnerable areas. • Interview people who encounter permafrost through their work (*i.e.*, digging holes) and add their information to the map.
P.6	Low	Government of Yukon	• Gather proxy data.
P.7		Government of Yukon	• Adopt greener codes. • Establish community monitoring programs.
P.8		City of Dawson	• Include access to mining areas in EMO considerations (*i.e.*, make equipment and skills available on an ad-hoc basis).

Access

Permafrost degradation, flooding, forest fire, or seasonal weather changes affects the transportation of people and goods into the community.

List of community consequences to reduced access.

Ref #	Consequence	Community Resilience			Priority
		Level of Impact	Likelihood	Adaptive Capacity	
A.1	• Increased frequency of flooding along the Klondike Highway isolates the community for longer periods of time.	High	High	Medium	High
A.2	• Changing permafrost conditions negatively affect travel and transportation along the Klondike Highway.	High	High	Medium	High
A.3	• Changing conditions exacerbate existing threats to the operation of the airport (*e.g.*, fog, flooding and smoke).	Medium	High	Medium/ High	Low
A.4	• Decreased reliability of ferry service, ice surfaces and ice-bridge due to shifting shoulder season conditions results in an increase in the isolation of hinterland communities.	High	High	Medium/ High	Medium

List of suggested adaptations to reduce risks from reduced access.

Ref #	Priority	Lead Partner	Suggested Adaptations
A.1	High	Tr'ondëk Hwëch'in, City of Dawson	• Develop preparedness programs in Dawson to cope with isolation. • Renew cultural memory of being self-sufficient. • Ensure resources are available in Dawson to quickly repair damage within city limits. • Increase local resilience through agriculture (*e.g.*, greenhouses). • Meet increased needs for local services. • Site contingency resources in strategic locations out of harms way.
A.2		Government of Yukon	• Inventory permafrost and identify vulnerabilities, including areas beyond the highway proper. • Explore the feasibility of technologies that will conserve the permafrost. • Enhance self-sustainability. • Develop infrastructure necessary to increase transportation on the Yukon River.
A.4	Medium	City of Dawson, Government of Yukon	• Develop preparedness programs in Dawson to cope with isolation. • Build a bridge across the Yukon River (this would also entail an upgrade to the Top of the World Highway) to ensure year-round access.

List of suggested adaptations to reduce risks from reduced access, *continued*.

Ref #	Priority	Lead Partner	Suggested Adaptations
A.3	Low	City of Dawson	• Examine alternatives to evacuations from the airport and include these in the EMO. • Some consideration may be given to relocating the airport as a long-term alternative. • Use alternative air service to Mayo.

Land Use

Changing land-use characteristics and conflicts arise with changing pressures created by climate-change impacts on the landscape in and around Dawson.

List of community consequences from increased land-use risks.

Ref #	Consequence	Community Resilience			Priority
		Level of Impact	Likelihood	Adaptive Capacity	
LU.1	• Agriculture expands and potentially conflicts with other land use types (*e.g.*, urban development, industry and wilderness areas). • Potential encroachment makes wilderness areas more important.	Medium	Medium	Unknown	High
LU.2	• Outbreak of new diseases in wildlife may occur if there is an increased reliance on domestic animals for food.	Low/ Medium	Medium/ High	High	Low
LU.3	• Established invasive species, such as leafy spurge, proliferate due to warming temperatures.	Medium	High	Medium	Medium
LU.4	• Fire frequency may increase if invasive species such as sweet clover spread along rivers and formerly uncolonized gravel islands, thus creating more fire hazards and decreasing areas that were formerly refugia.	Unknown	High	Low	High
LU.5	• New invasive species are introduced through new agricultural experiments and land uses (*e.g.*, use of exotics to landscape downtown core).	Medium	Medium/ High	Low/ Medium	Medium
LU.6	• Unfamiliar and variable water levels negatively impact salmon fishing.	Medium	High	High	Low
LU.7	• Country food availability (*e.g.*, moose, caribou, salmon) declines because birthing cycles fall out of sync with the seasons (*e.g.*, moose may have their calves at the wrong time of year leading to increased predation and a decline in population).	High	Low	High	Low

List of community consequences from increased land-use risks, *continued*.

Ref #	Consequence	Community Resilience			Priority
		Level of Impact	Likelihood	Adaptive Capacity	
LU.8	• Warming water leads to a decline in salmon abundance.	High	High	Low	High
LU.9	• Climate change negatively affects forest ecology and timber harvests.	High	Medium/ High	Low	High
LU.10	• Wildlife populations in recovery, notably the Fortymile caribou herd, are negatively affected if grazing range is reduced as treeline climbs and forest fires may burn the lichen off.	Medium	Low	Low	Medium
LU.11	• Existing stresses (*e.g.*, habitat loss and fragmentation) on wildlife populations are exacerbated by climate-induced changes to the timing and pattern of wildlife migrations which directly affects harvesting.	Medium/ High	Medium/ High	Low	High

List of suggested adaptations to land-use issues.

Ref #	Priority	Lead Partner	Suggested Adaptations
LU.1	High	YLUPC, Government of Yukon	• Incorporate flexible regulations and policies into land-use planning and all other rural planning processes (*e.g.*, local area planning, environmental assessments, *etc.*).
LU.4		Government of Yukon	• Continue weed pull programs. • Monitor the spread of invasive species.
LU.8		Tr'ondëk Hwëch'in	• Seek alternative food sources (in keeping with current efforts). • Explore the feasibility of a fish hatchery. • Communicate to present and future generations the need to respect fish and wildlife. • Educate the public on the impacts of the commercial fishery.
LU.9		Government of Yukon	• Ensure that climate change is incorporated into forestry management plans. • Support ongoing forestry studies that examine climate-change impacts on local tree species*.
LU.11		YLUPC, Government of Yukon	• Incorporate climate change into land-use planning. • Follow Arctic Borderlands Ecological Co-op model, *i.e.*, use traditional and scientific resources when gathering data . • Develop and implement less invasive methods of monitoring. • Study how small animals toward the bottom of the food chain react to climate change.
LU.3	Medium	Government of Yukon	• Monitor invasive species and take action where necessary.
LU.5		Government of Yukon	• Establish inspection programs and/or determine where and when to ban the import of plants and animals.

List of suggested adaptations to land-use issues, *continued.*

Ref #	Priority	Lead Partner	Suggested Adaptations
LU.10	Medium	Tr'ondëk Hwëch'in, Government of Yukon	• Continue to protect the lichen fields, *i.e.*, if managed properly, a thriving Fortymile caribou herd could become a valued local resource.
LU.2	Low	Government of Yukon	• Ensure adequate fencing standards are developed and put in place to separate domestic animals from wildlife. • Investigate the potential impacts of endemic and invasive parasites on moose.
LU.6		Tr'ondëk Hwëch'in, Yukon River Panel	• Find and implement alternatives to current salmon fishing methods (*e.g.*, move fishing sites, use different gear, *etc.*).
LU.7		Tr'ondëk Hwëch'in, Government of Yukon	• Monitor, and if necessary, change harvesting regimes. • Resume using traditional laws for gathering and hunting. • Consume alternative foods. • Restart experimental farms (*e.g.*, Swede Creek). • Assess the impact climate change may have on traditional knowledge. • Assess the availability and utilization of country foods in the Dawson region.

*For example, the UNBC/YG project assessing the Vulnerability to Climate Change and Adaptive Capacity of Yukon Forest Tree Species and Ecosystems.

Health

Shifting climate conditions affects the universal health of residents. The mental health of residents declines as a result of environmental or social changes, such as a rise in unemployment. Changing climate conditions leads to reduced availability of country foods and subsequent effects on the physical health of residents.

List of community consequences of increased health risk.

Ref #	Consequence	Community Resilience			Priority
		Level of Impact	Likelihood	Adaptive Capacity	
H.1	• Climate change exacerbates existing mental health issues such as the incidence of Seasonal Affective Disorder (SAD) in the event of an increase in the frequency of overcast skies.	Medium	Medium/ High	High	Medium
H.2	• Unpredictable conditions associated with climate change increases anxiety.	Low	Medium/ High	High	Low

List of community consequences of increased health risk, *continued.*

Ref #	Consequence	Community Resilience			Priority
		Level of Impact	Likelihood	Adaptive Capacity	
H.3	• Conditions of residential homes could deteriorate further, leading to health problems (*e.g.*, increased incidence of dampness and mould in housing, permafrost thaw, *etc.*).	High	High	Low	High
H.4	• In the event of the reduced availability of country foods, an increased consumption of commercial foods could lead to subsequent health effects (*e.g.*, increased obesity, diabetes, *etc.*).	Medium/ High	High	High	Low/ Medium
H.5	• The passing-on of hunting traditions suffers as landscape conditions change.	Medium	Medium/ High	High	Medium
H.6	• A higher incidence of forest fires affects air quality around Dawson.	High	High	Low	High

List of suggested adaptations to increased health risk.

Ref #	Priority	Lead Partner	Suggested Adaptations
H.3	High	City of Dawson, Government of Yukon	• Ensure building codes are congruent with the expectations of a changing climate. • Implement newer building technologies that provide more energy efficiency and better ventilation . • Monitor the present conditions in problem buildings. • Continue education on potential health risks (*e.g.*, recent campaigns supporting donation of recyclables, need for immunizations, *i.e.*, West Nile virus). • Explore methods for improving the quality of heritage building stock.
H.6		Government of Yukon	• Update building codes to ensure cost and energy efficiency, ensure indoor air quality, make sure building codes reflect improved wild fire safety standards, and establish operational & maintenance cost effectiveness. • Develop programs to encourage people to wear masks and/or stay in indoors when severe fires occur. • Increase resources for fire prevention.
H.1	Medium	City of Dawson	• Ensure recreational opportunities are provided during daylight hours.
H.5		Tr'ondëk Hwëch'in	• Maintain awareness of changes as they relate to climate change and ensure communication. • Emphasize cultural activities (*e.g.*, First Hunt/First Fish). • Involve youth (*e.g.*, organize local field trips such as taking children up the Dempster Highway).

List of suggested adaptations to increased health risk, *continued.*

Ref #	Priority	Lead Partner	Suggested Adaptations
H.4	Low/ Medium	Tr'ondëk Hwëch'in, City of Dawson	• Identify health alternatives when selecting foods. • Promote recreation. • Provide community/social centre. • Create a project to teach locals about gardening.
H.2	Low	Tr'ondëk Hwëch'in, City of Dawson	• Clearly communicate where vulnerabilities exist and what the implications are for the community. • Communicate climate-change vulnerabilities in a less alarmist manner. • Lower expectations and anticipate changes to occur. • Increase social network support. • Help volunteer organizations focus initiatives.

Economy

An economic downturn is generated by the effects of climate change events and impacts.

List of community consequences due to increased economic risk.

Ref #	Consequence	Community Resilience			Priority
		Level of Impact	Likelihood	Adaptive Capacity	
E.1	• The sustainability of emerging activities, such as wilderness and arts businesses, could be affected by unpredictable market fluctuations stemming from climate change.	High	High	Low	High
E.2	• Sporadic disruptions to the tourism market potentially results in increased unemployment.	Low/ Medium	High	High	Low
E.3	• Cost increase to goods and services results as transportation is challenged by infrastructure disruption.	High	High	Medium	Medium/ High
E.4	• Cost of responding to permafrost degredation exceeds community resources.	High	Low	Medium	Medium
E.5	• Gift shops, restaurants and hotels are negatively affected by decline in tourism and worsening transportation conditions (*i.e.*, subsequent dwindling of local business as tourism economy slows and annual maintenance costs increase).	High	Low/ Medium	Medium/ High	Medium
E.6	• Increased expenditure on groceries if the availability of country foods declines.	High	High	Medium/ High	Medium

List of community consequences due to increased economic risk, *continued.*

Ref #	Consequence	Community Resilience			Priority
		Level of Impact	Likelihood	Adaptive Capacity	
E.7	• Warmer temperatures make it difficult to preserve chum in the open air, which is important for local dog mushers (*e.g.*, under normal conditions fish rots and dries a little, while the cold keeps the flies off and then freezes the chum).	Low/ Medium	High	Medium/ High	Low
E.8	• Increased reliance on air conditioning results in increased summer living costs.	Low/ Medium	Medium/ High	High	Low

List of suggested adaptations to increased economic risk.

Ref #	Priority	Lead Partner	Recommended Adaptations
E.1	High	City of Dawson	• Diversify economy by supporting emerging markets. • Rebrand community marketing strategy to offset long distance aspect of travel (*e.g.*, create slogans such as "You've come so far to get here; stay a little longer"). • Emphasize grassroots culture/unique events (*e.g.*, music festival).
E.3	Medium/ High	City of Dawson, Government of Yukon	• Use local materials when implementing projects. • Adapt airport to shifting climate conditions (*e.g.*, relocate air strip).
E.4	Medium	City of Dawson, Government of Yukon	• Establish government responsibilities. • Engage citizens. • Plan for potentially relocating the community. • Establish contingency plans for heritage buildings.
E.5		City of Dawson	• Change tourism strategies. • Favour local businesses.
E.6		Tr'ondëk Hwëch'in, City of Dawson	• Increase local food production.
E.2	Low	City of Dawson	• Maintain existing services. • Invest in alternative transportation.
E.7	Low	Community Groups, Government of Canada	• Fish later in the season. • Buy dogfood.
E.8		City of Dawson, Government of Yukon	• Plant shade trees to increase cooling in the downtown core. • Encourage the use of efficient home insulation.

OPPORTUNITIES

Fourteen opportunities were identified in the Dawson community climate change scenario. Opportunities stemmed from climate-induced changes to the regional forest fire regime, seasonal weather changes, tourism and recreation, permafrost degradation, and a more robust local economy that will likely benefit residents. Priority opportunities were identified based on

the existing adaptive capacity of residents to respond to favourable conditions and the likelihood that the opportunity would emerge.

List of anticipated community opportunities associated with climate change.

Ref #	Vulnerability Type	Climate-Related Opportunity	Likelihood	Adaptive Capacity	Priority
O.1	Forest Fire	• Forest fire has a positive effect on mushroom harvest.	High	High	Low
O.2		• Increases in available temporary employment as more fire fighters are required.	Medium/ High	High	Low
O.3		• Increased opportunity for ecosystem tours of fire-devastated areas.	Low	Medium	Low
O.4		• Changes to fire regime creates short-term opportunities to collect timber for use in heating.	Medium/ High	High	Low
O.5	Seasonal Weather Changes	• Mining season is extended as a result of a warming climate.	High	High	Low
O.6		• Decreased heating costs due to warmer shoulder seasons.	High	High	Low
O.7		• Warmer climate conditions (*i.e.*, warmer, wetter springs and a longer frost-free period) yield longer growing seasons, and an increase in agricultural productivity.	Medium/ High	Medium	Medium
O.8		• Warmer growing conditions lead to a greater variety of crops that can be reliably grown.	High	Medium	Medium/ High
O.9		• Increased yields from local harvests develop as a result of increased productivity regionally.	Medium/ High	Medium	Medium/ High
O.10	Tourism and Recreation	• Warmer climate conditions extend tourism and recreation seasons.	Medium/ High	High	Low
O.11		• Conditions for recreation improve, *e.g.*, increased snowfall for skiing.	Medium/ High	Low/ Medium	High
O.12		• Reliably extended tourism season benefits businesses and outfitters.	Medium/ High	High	Low
O.13	Economy	• Household costs and seasonal budgets change with warmer summers and shorter winters.	High	Medium/ High	Low
O.14	Permafrost Degradation	• Permafrost degradation reduces the cost of preparing the ground for mining.	Medium	High	Low

List of suggested adaptations to support opportunities.

Ref #	Priority	Lead Partner	Suggested Adaptations
O.11	High	City of Dawson	• Advertise new tourism and recreation opportunities. • Update/implement OCP recommendations relating to Recreation, Parks and Open Space (Section A.5.5). • Explore the expansion of existing trail networks. • Coordinate ski hill expansion with EMO implementation. • Incorporate local infrastructure and natural features into climate-change adaptation (*e.g.*, convert firebreaks to trails). • Groom trails and purchase a snow-making machine for Moose Mountain.
O.8	Medium/ High	Tr'ondëk Hwëch'in, Government of Yukon	• Re-establish experimental farms (*e.g.*, Swede Creek).
O.9		Tr'ondëk Hwëch'in, City of Dawson	• Explore vegetable storage options. • Investigate possible markets for agricultural surplus (if necessary). • Advertise local produce.
O.7	Medium	Tr'ondëk Hwëch'in, City of Dawson	• Support community garden initiatives (including education and technologies). • Identify an existing community that is similar to Dawson that will also help to identify successful agricultural opportunities. • Develop skills to capitalize on opportunities related to seasonal weather changes.
O.1	Low	Tr'ondëk Hwëch'in, Government of Yukon	• Provide maps of prime mushroom areas. • Develop educational resources on mushroom identification, collection and storage.
O.2		City of Dawson, Yukon College	• Continue to offer training in fire-fighting.
O.3		City of Dawson, Government of Yukon	• Provide interpretive opportunities (*e.g.*, increase forest fire interpretation).
O.4		Government of Yukon	• Ensure reforestation to maintain healthy forests. • Salvage wood for heating purposes. • Increase the overall salvage component of forest harvest.
O.5		Government of Yukon	• Monitor the effects of seasonal weather changes as required.
O.6		Tr'ondëk Hwëch'in, City of Dawson	• Concentrate on local fuel sources. • Change lifestyles to further save on fuel costs.
O.10		City of Dawson, Government of Yukon	• Advertise longer tourism season. • Change tourism strategy to accommodate longer season.
O.12		Government of Yukon	• Encourage protected area designation to maintain wilderness values.

List of suggested adaptations to support opportunities, *continued.*

Ref #	Priority	Lead Partner	Suggested Adaptations
O.13	Low	Tr'ondëk Hwëch'in, City of Dawson	• Explore alternative heating and cooling resources in order to reduce costs further.
O.14		Community Groups, Government of Yukon	• Enjoy the good changes - remain positive. • Explore the potential for development in areas where permafrost is stable, or is absent.

CLIMATE CHANGE ADAPTATION AND DAWSON

While this work has documented a range of community concerns about the possible impacts of a changing climate in the Dawson region, it also demonstrates that the prognosis for future events is clouded with considerable uncertainty. This is not surprising. There are some substantial gaps in the scientific record that render robust scenario building difficult. These gaps are in and of themselves a basis of vulnerability. Regardless, the well-documented exposures of Dawson to the physical environment (see *Community Profile, History of Environmental Stresses*, p. 17) makes it highly vulnerable to the potential repercussions of a changing climate, reinforcing the need for a community-based, proactive approach to dealing with the urgencies of a changing environment.

The following adaptations are recommended to address high priority climate-change vulnerabilities/opportunities that are characterized by an immediate need and anticipated feasibility. In general, the recommended adaptations are intended to respond to more than one community vulnerability and/or respond to any climate-change opportunities that may emerge. It is anticipated by the project team that the needs of the community will evolve over time and as the effects of climate change unfold. For this reason, it should be noted that recommended adaptations look to the immediate future as suggested by residents based on their local knowledge. Additional needs may arise over time and future decision makers should consider that the actions or lack of actions we take now will set the stage for the future.

It is anticipated that over time, improved climate-change projections and additional scientific research supporting future changes will allow for greater certainty in decision making. For example, it is anticipated that the scientific findings of IPY studies will contribute greatly to our understanding of the regional effects of climate change in the Western Arctic. For the immediate future, it is suggested that the recommendations of this plan be implemented in keeping with upcoming global timetables. Specifically, the global community is advising that emission controls are necessary and that specific carbon cuts will be required by 2020. At that time, based on the success of nations to curb their carbon emissions, communities will have greater certainty of the severity of the climate changes that they must face. We therefore suggest that the following actions be taken in the Dawson region by 2020; these actions should be led by the community and supported by the lead partners identified in the previous section (*Climate-Induced Vulnerabilities and Opportunities*). We also recommend that this plan be updated by the year 2020 to reflect the success or failure of the global community to curb their carbon emissions.

ADAPTATIONS RECOMMENDED FOR IMMEDIATE IMPLEMENTATION

- Maintain or develop research and monitoring to observe changes (*e.g.*, environmental, socio-economic, infrastructure, *etc.*) and evaluate possible climate-change impacts and responses.
- Integrate climate-change assessment into rural planning processes.
- Update the Emergency Measures Ordinance (EMO) to reflect possible climate-change vulnerabilities.
- Investigate the need to raise the existing level of the dyke. Determine who is responsible for the work.
- Examine the flood risk for the Tr'ondëk Subdivision.
- Investigate flood proofing of the proposed sewage facility.
- A detailed permafrost assessment that is publicly available is required, which could build on/update the assessment completed by EBA in the 1970s.
- Continue highway vulnerability assessment and action planning (*e.g.*, build on experiences in and around Beaver Creek, YT).
- Complete the hydrogeological testing of the Quigley Solid Waste Facility.
- Designate fiscal responsibility for remediation of abandoned waste disposal sites.
- Explore the feasibility of technologies that will conserve permafrost.
- Continue weed-pull programs.
- Communicate the need to respect fish and wildlife to present and future generations.
- Diversify economy by supporting emerging markets.
- Use local materials when implementing projects.
- Update and implement the Official Community Plan (OCP) recommendations relating to Recreation, Parks and Open Space (see Section A.5.5 of the OCP).
- Advertise local produce.
- Explore vegetable storage options.
- Investigate possible markets for agricultural surplus (if necessary).
- Educate the general public on the impacts of the commercial fishery.
- Test less invasive ways for studying wildlife (*e.g.*, salmon).

ADAPTATIONS RECOMMENDED FOR IMPLEMENTATION BY 2020

- Implement preparedness education to respond to potential climate change-related emergencies.
- Ensure resources necessary to repair damage within the plan boundary are available.
- Develop education programs to assist residents in making sound decisions when coping with, or preparing for, climate-induced changes in the community.
- Re-establish experimental farms (*e.g.*, Swede Creek) and investigate local agricultural options and alternatives.

- Develop and/or release information about possible flooding.
- Investigate the potential of drought and its impacts on the Dawson region.
- Create emergency storm shelter systems within the community.
- Construct a helicopter pad for emergencies as needed.
- Change road materials, *i.e.*, use stronger materials.
- Develop monitoring programs in the area that will document changes in water quality.
- Complete a risk assessment that also inventories abandoned dump sites in the Dawson area.
- Incorporate flexible regulations and policies into rural land-use planning.
- Explore the feasibility of a fish hatchery.
- Ensure that climate change is incorporated into forestry management plans.
- Study how small animals toward the bottom of the food chain react to climate change.
- Ensure building codes are congruent with the expectations of a changing climate.
- Re-brand community marketing strategy to offset long-distance aspect of travel (*e.g.*, create slogans such as “You’ve come so far to get here; stay a little longer”).
- Emphasize grassroots culture and unique community events (*e.g.*, music festival).
- Expand existing trail networks.
- Coordinate ski-hill expansion in conjunction with EMO implementation.
- Incorporate local infrastructure and natural features into climate-change adaptation (*e.g.*, convert firebreaks to trails).

NEXT STEPS

Some selected adaptations will be implemented as a component of the Dawson Adaptation Project with funding provided by the Northern Strategy Trust. These projects will be selected by the Dawson Local Advisory Committee. To ensure the selection of relevant and successful implementation projects, the Local Advisory Committee prepared the following terms of reference:

- Have broad appeal.
- Have high visibility.
- Have high relevance/utility.
- Produce readily measurable results.
- Reduce the carbon footprint of the community, or have a minimal footprint.
- Leverage other funding.
- Attract partners.
- Be built upon later.
- Provide local employment.

- Tie into and/or build upon existing plans.
- Increase local resilience.
- Use local resources and materials.
- Be characterized by financial sustainability that continues past the implementation deadline (July 2010).

Projects will be implemented from 2009 to 2010 by the Dawson Adaptation Coordinator. A full implementation report will be provided at the conclusion of the implementation period in summer 2010.

MAINSTREAMING CLIMATE CHANGE IN THE COMMUNITY

Mainstreaming climate change is the integration of climate change into standard planning efforts. In addition to the explicit connections to the Dawson ICSP noted in section *Community Profile – Sustainable Development in Dawson* (p. 19), many of the adaptations identified in this plan can be integrated into other plan development or updates. Specifically, the planning team has identified how climate change may influence a future update of the Dawson OCP, land-use planning in the region, emergency response planning, fire management planning and infrastructure planning. For the purposes of mainstreaming climate change, we suggest the following for consideration by future decision-makers:

Land-use/local area planning:

- Assess and respond to ongoing regional vulnerability assessments.
- Utilize ongoing monitoring to support updates to land-use plan recommendations.
- Incorporate flexible regulations and policies into rural land-use planning.

Sustainability planning:

- Continue weed-pull programs and monitor the spread of invasive species.
- Seek alternative food sources (in keeping with current efforts).
- Explore the feasibility of a fish hatchery.
- Assess the availability and utilization of country foods in the Dawson region.
- Update building codes to ensure cost and energy efficiency, ensure proper indoor air quality, and establish operational and maintenance cost effectiveness.
- Improve on wildfire safety standards and increase resources for fire prevention.
- Develop programs to encourage people to wear masks or stay in indoors during severe forest fires.
- Explore vegetable storage options.
- Investigate possible markets for surplus agriculture (if necessary).
- Support community garden initiatives (including education and technologies).
- Develop skills to capitalize on opportunities.
- Develop educational resources on mushroom identification, collection and storage.
- Provide interpretive opportunities to enhance tourism (*e.g.*, increase forest fire interpretation).

- Salvage wood for heating purposes.
- Increase the salvage component of forest harvest.
- Change tourism strategy to accommodate for a potentially longer season.
- Encourage the designation of protected areas in order to maintain wilderness values.
- Explore alternative heating and cooling methods that may further reduce costs.
- Establish monitoring procedures in the area in order to document changes in water quality.
- Complete the hydrogeological testing of the Quigley Solid Waste Facility.
- Complete a risk assessment that inventories abandoned dump sites in the Dawson area.
- Determine the potential severity of permafrost degradation under Parks Canada buildings; relocate vulnerable buildings if necessary.
- Use methods of travel that require less infrastructure development, such as smaller and less-traveled roads. Plan and develop new foot and ski trails.
- Provide information on how to diversify and promote a healthy diet.
- Develop preparedness programs in Dawson to cope with isolation.

Emergency measures planning:

- Update flood response plan.
- Ensure EMO updates refer to the flood-risk and climate-change assessment when completed.
- Consider fire vulnerability when building new residences.
- Review and update fire response plan, and provide more fire breaks.
- Establish peripheral (West Dawson) fire support.
- Improve fire defenses.
- Increase communication and provide public education on emergency protocols.
- Increase household preparedness education.
- Complete evacuation planning.
- Include access to mining areas in EMO considerations (*i.e.*, consider the use of heavy equipment and ensure that the required operational skills are available on an ad-hoc basis).
- Provide contingency resources in locations that are out of harm's way.
- Examine the alternatives to evacuations from the airport and add to the EMO. Some consideration may be given to relocating the airport as a long-term alternative.
- Coordinate ski-hill expansion in conjunction with EMO implementation.
- Transport goods and people via convoys along the highway into the community during periods of impaired sight due to heavy smoke from forest fires.
- Investigate the feasibility of developing a severe storm warning system.
- Investigate the need for a helicopter pad for use during emergencies.

Official community planning:

- Ensure adequate fencing standards are developed and put in place to separate domestic animals from wildlife.
- Ensure building codes are congruent with the expectations of a changing climate.
- Plant shade trees to increase cooling in the downtown core.
- Update and implement OCP recommendations relating to Recreation, Parks and Open Space (see Section A.5.5 of the OCP).
- Explore the potential for development in areas where permafrost is stable, or is absent.
- Consider fire vulnerability when building new residences.
- Ensure two access routes into Dawson via the Top of the World Highway.

Infrastructure planning:

- Continue vulnerability assessment and action planning (*e.g.*, build on experiences and expertise acquired in the Haines Junction area).
- Ensure resources are available to respond to infrastructure challenges as they arise.
- Change road construction materials, *i.e.*, use flexible materials or materials that can be easily replaced.
- Inventory and characterize permafrost and identify vulnerabilities, including areas beyond the highway proper.
- Explore the feasibility of technologies that will conserve permafrost.
- Investigate the need to raise the existing level of the dyke. Determine who is responsible for the work.
- Examine the flood risk for the Tr'ondëk Subdivision.
- Ensure roads are kept clear of snow and ice during spring melt.
- Investigate alternative road-surfacing performance.

ADDRESSING UNCERTAINTY AND CLIMATE CHANGE IN THE DAWSON REGION

While some uncertainty is a normal aspect of climate change, there is an overall lack of scientific data available in order to provide a clear and concise climate-change assessment. For example, Brooks *et al.* (2009) state: "The most significant barriers to adaptation identified in *[Prioritizing Climate Change Risks and Actions on Adaptation]* are access to knowledge, data and decision support tools, specific regulations or legislation that may limit adaptation options and societal expectations."

While this report has made every attempt to integrate uncertainty productively into the evaluation of adaptation, every effort should be made to reduce the level of uncertainty associated with adaptation decision making. This section is intended to suggest strategies for reducing uncertainty that were not explicitly determined through the process for identifying the recommendations of this report.

Integration of Climate-Change Mitigation and Adaptation

As noted previously, many adaptations can contribute to the mitigation of climate change. Unlike adaptation however, climate-change mitigation has a far more specific agenda (*i.e.*, the reduction

of greenhouse gas emissions) and mitigation actions are therefore subject to far less uncertainty. The integration of mitigation and adaptation measures will likely generate a more robust action strategy by providing a solid rational for action, in addition to providing the balanced and effective response to climate change suggested by the IPCC (IPCC, 2007b).

Monitoring and Research

Research is essential for addressing the uncertainty associated with the adaptation decision-making process. Unfortunately, the availability of funding and research partners typically determines what research is undertaken in Yukon and when. To reduce uncertainty in climate change decision-making processes, it is suggested that a research agenda be determined that increases the cohesiveness of future research in the Dawson area. Such an agenda could suggest climate change indicators and identify where prominent gaps exist in the current knowledge base. The collaborative nature and emphasis on investigating uncertainty associated with adaptive management frameworks may be advantageous if applied to a climate change research agenda in Yukon.

Dawson is strategically situated to be a player in emerging global, circumpolar, national and pan-northern research and monitoring networks (I. Church Yukon Government, pers. comm., 2009). For example, there is a new initiative that is examining climate-change issues in the Pacific Northwest/Northern Cordillera and comprises a large number of partners including the University of Alaska Fairbanks, University of Northern British Columbia, University of Calgary, University of Alberta and Yukon College. It is critical that any monitoring program gets linked to larger initiatives so that comparable data is available, and to allow the network to provide an early warning system.

As with research, monitoring is also limited by economic and human capital. While community-based monitoring programs (*e.g.*, The Arctic Borderlands Ecological Knowledge Co-operative) have been implemented successfully, such programs remain subject to many limitations. It is suggested that in addition to a cohesive research agenda, the lead partners noted previously (see section *Climate-Induced Vulnerabilities and Opportunities,* p. 29) should collaborate to deliberate the most effective way to implement a climate-change impacts monitoring program.

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APPENDIX A - DAWSON ADAPTATION PROJECT COMMITTEE MEMBERS

Whitehorse Local Advisory Committee (LAC) Membership.

Members	Affiliation
Renee Mayes	Tr'ondëk Hwëch'in Government Land Use Coordinator
Norm Carlson	City of Dawson Public Works Manager
Jim Taggart	President, Klondike Conservation Society
Mark Wickham	Chair, Klondike Visitors Association
Jim Regimbal	City of Dawson Fire Chief
John Lenart	Chair, Yukon Agriculture Association
Gerry Couture	Mining and Fishing and Water

Whitehorse Technical Advisory Committee (TAC) Membership.

Members	Affiliation
Al von Finster	Yukon and Transboundary Issues, Department of Fisheries and Oceans
Antoni G. Lewkowicz	Department of Geography, University of Ottawa
Trix Tanner	Education Coordinator, Department of Fisheries and Oceans
Aynslie Ogden	Forest Management Branch, Government of Yukon
Bob Van Dijken	Yukon IPY Coordination Office, Council of Yukon First Nations
Ian Church	Executive Council Office, Government of Yukon
Jody Butler-Walker	Arctic Health Research Network - Yukon
Mark Stephens	Mineral Resources Branch, Energy Mines and Resources, Government of Yukon
Michael Purves	Meteorologist (retired), Environment Canada
Norma Kassi	Arctic Health Research Network - Yukon
Rick Janowicz	Hydrology Section, Department of Environment, Government of Yukon
Robert Clark	Tourism Product Development and Research, Department of Tourism and Culture, Government of Yukon
Robin Walsh	Transportation Engineering, Department of Highways and Public Works, Government of Yukon
Val Walker	Social Economy Research Network of Northern Canada, Yukon College

APPENDIX B - DAWSON COMMUNITY INPUT WEEK PARTICIPANTS

Land-Based Occupations and Traditions: 12 November 2008

Sebastian Jones
Gladys Netro
John Lenart
Jim Taggart
Bill Kendrick
Hans Algotsson

Local Economy: 13 November 2008

John Steins
Jody Beaumont
Alex Brook
Dina Grenon
Gerry Grenon
David Curtis
Lori Carter
Marta Selassie
Sebastian Jones

Infrastructure and Planning: 14 November 2008

Steve Geick
Ian MacDonald
Helen Winton
Renée Mayes
Alex Brook
Jim Regimbal
Mike Fraser
Norm Carleson
Ron Bramadat
Jim Taggart
Sebastian Jones